





SOCIETY FOR THE ENCOURAGEMENT

OF

ARTS, MANUFACTURES, AND COMMERCE.

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CANTOR LECTURES

ON

RECENT ADVANCES IN  
PHOTOGRAPHY,

BY

CAPTAIN ABNEY, R.E., F.R.S.

DELIVERED BEFORE THE SOCIETY OF ARTS, JANUARY AND FEBRUARY, 1882.

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# RECENT ADVANCES IN PHOTOGRAPHY,

BY CAPTAIN ABNEY, R.E., F.R.S.

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## LECTURE I.—DELIVERED JANUARY 30TH, 1882.

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In beginning this course of Cantor Lectures, I make this presumption—that amongst my audience I have those who have commenced photography but recently; also, those who commenced photography about the time I did, say twenty years ago; and that there are very few now who practice those old processes which our forefathers, if I may use the expression, were accustomed to manipulate. I have also reason to believe that amongst my audience there are some who know very little of photography at all. I must try and do the best I can to address myself to all. It is a difficult thing; but I hope those to whom I am not exactly fitting my remarks at any time, will remember that I am addressing others, who I also have to consider.

I thought, perhaps, it might be useful to go over the very oldest processes with which photography started; and when you recollect that photography is not very old—in fact, is a chicken compared with some of the sciences, although there are many amongst us who can remember its discovery, I think it may be of interest if you see worked out practically before you these very early processes to which I refer.

The first germ of photography was when Scheele investigated the action of light on silver chloride, and found that it discoloured it. It was subsequently found that this discolouration of the chloride was due to a liberation of chlorine from the chloride of silver. In 1802, eighty years ago, Wedgwood read a paper before the Royal Institution, in which he described a method of taking profiles, and also copying painted pictures, by means of what we should now call photography. These profiles were taken on paper washed over with silver nitrate. In other words, the profile of the person to be portrayed was thrown against sensitised

paper, in a strong light, and the outline was photographed or made visible by the strong light acting outside the profile. Of course it produced a white profile on a black background. About the same time that Wedgwood read this paper, Sir Humphry Davy was practising this process, and he found that silver chloride was preferable to silver nitrate. He also found that if he used white kid as a basis of what I will call the photograph, he got a stronger impression than if he used simply paper. In 1814, twelve years later, Niépce devoted himself to studying the action of light upon asphaltum, and he worked out a process which up to this day is still used, and which I shall not refer to more particularly now, as I shall hope to do so in a subsequent lecture. He developed the process which was then called heliography, which consisted in the production of a picture in bitumen on a metal plate, the light causing the oxidation of the bitumen or asphaltum, and rendering insoluble or less soluble those parts which had been acted upon.

In 1827, Niépce came to England, and endeavoured to introduce the results which he had obtained to the notice of the Royal Society; but, owing to the process being a secret one, the communication was not received.

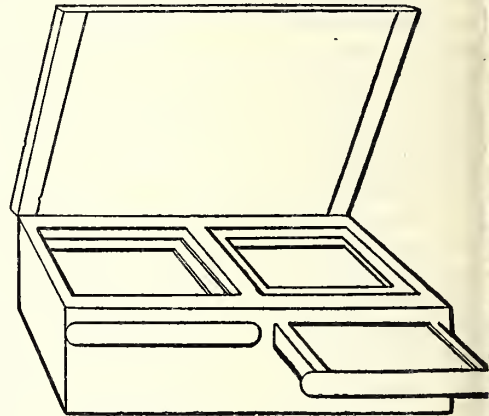
In 1824, Daguerre, a name to be remembered, a French painter, began similar experiments in the same direction, and, in 1829, he and Niépce entered into partnership to work out that which eventually received the name of photography. Now, Niépce has left it on record, that in his bitumen pictures he had one considerable trouble: he found that, instead of the lines of an engraving being represented by black stains on the white metal, the lines were represented by white metal on black bitumen. In order to overcome this difficulty,

after coating the silver plate with his bitumen, and developing it by dissolving away the unaltered parts, he treated the metallic silver plate beneath with any ingredient which he might choose, and amongst others, he has left on record that he treated it with iodine, and then rubbed off the bitumen. This, in the case of an engraving, would of course give dark lines on a white background. Here we have the first mention of iodine and silver.

Now, we cannot suppose that two such shrewd observers as Niépce and Daguerre could have used this combination of iodine and silver without noticing that it was altered by light; and I may say that there are a number of grave grounds for considering that this was really the origin of the daguerreotype process, which consists, as you know, in the treatment of a silver plate primarily with iodine, and subsequently with other substances, to cause sensitiveness. Daguerre and Niépce must have noticed the alteration by light in the silver iodide which they had formed on the silver plate, but up to that time of which I am talking, they had not discovered the secret of what we now call development. And when we come to consider the early history of photography, it is a most remarkable fact, that the two first modes of development were discovered, if I may say so, by flukes. The discovery of the development of the daguerrean image was as follows:—Daguerre had been trying to reduce the exposure of iodide of silver to light, in order to get an image in a reasonable time. Instead of exposing his plate for a quarter of an hour or an hour, he wished to obtain an image in one or two minutes, which, to him, would have been very quick. Many months were passed in these apparently fruitless researches, until one day he placed one of his iodised plates, which he had exposed to light for some short time, in his chemical cupboard. Now, in that chemical cupboard were a variety of bottles of all descriptions. He had worked hard, and as chemists know perfectly well, when a man is working at research, there is usually a collection of all sorts of chemicals. He placed his daguerreotype plate in the cupboard over night, and to his astonishment, next morning, when he opened the cupboard, he found that he had a fully developed daguerrean image. This was a discovery which he immediately turned to account. He exposed other plates, shifting first one bottle then another, and by this process of elimination, at last he was able to find

that it was an open bottle of mercury which had caused the development of the image. This was really, I believe, the true history of the daguerreotype process, so far as the mercurial development was concerned. It was considered a very short exposure in those days, if you sat five or ten minutes in the sunlight to have your portrait taken. We have changed all that now, and I dare say before this course of lectures is over, not only five or ten minutes will be considered a long exposure, but perhaps  $\frac{1}{1000}$ ths of a second will not be considered short.

I have the pleasure to-night of introducing to your notice, an old worker of the daguerreotype process, Mr. England. He has kindly consented to show the whole manipulation of the process from beginning to end, thinking it might interest what I may call a juvenile audience, for juvenile I suppose most of you are, as regards photography. Mr. England has left me to do the talking, and therefore I must do the best I can to explain the operations which will be gone through. We have a little box, divided into two parts,



DAGUERREOTYPE DEVELOPING BOX.

in one of which is placed iodine, and in the other is placed what is called bromide of lime, that is to say, caustic lime, impregnated with bromine. You will find that, first of all, having polished it, he will place the plate over one of these apertures—over the iodine; the iodine vapour will be allowed to play upon it a certain time, and then he will shift the plate over to the bromine, and thus he bromises the silver. He will finally give it another touch of iodine vapour, and the plate will be ready for exposure. Mr. England has taken the trouble to polish these plates beforehand, since their polishing is one of the chief difficulties of

the daguerreotype process. The fact is, the plates require the most elaborate polish, such as even a silversmith can scarcely give them. One of these plates he will now place over the iodine, and for two minutes allow the iodine vapour to rise and attack the silver. [Mr. England here explained that the first process is to bring the plate to a deep yellow colour, by means of the iodine, and then to place it over the bromine.] In the first place, it is necessary to be able to see the colour, so that a reflector is placed on the one side of the sensitising box, the other being open. By this artifice, the plates may be viewed, and the colour of the daguerreotype plate can be watched, till it has attained a deep yellow colour. It is passed on, to be acted on by the bromine, and that is continued until it attains a rose colour. It is a little difficult, by artificial light, to see the exact colour; this process was seldom worked by artificial light, and, therefore, one may be misled by false colour.

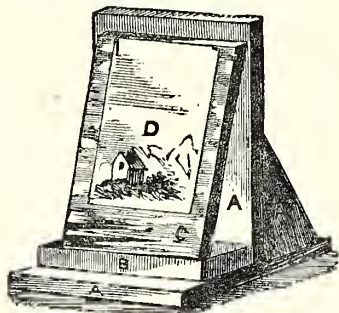
We propose, between us, to take a daguerreotype picture. Now, the operation of sensitising is very nearly finished. It has been treated with iodine, and then with bromine, and now it is having a final submission to iodine. The plate Mr. England prepared has now been exposed one minute; Mr. England is rather doubtful about the sensitiveness of the plate, but I am afraid, myself, it is rather over-exposed. Mr. England is now going to develop the picture, and he will do so by the use of mercury. He has here the original mercury box with which he was accustomed to manipulate. He will hang it against the wall, and light a small spirit lamp under a bowl of mercury beneath it. The mercury fumes will rise through an orifice into the box, and so on to a plate; he will watch it from time to time, until it is developed, when we will show it to you. [A copy of an engraving was here taken whilst illuminated by the electric light.]

I should like you to understand exactly what takes place in the daguerreotype plate when it is exposed and developed. On the surface of the plate we have a mixture of silver iodide and bromide, but, for simplicity's sake, I will suppose that there is simply silver iodide on it. When light acts on such a compound, the action is to split up the silver into a salt, which we call silver sub-iodide, and iodine is liberated,  $\text{Ag}_2 \text{I}_2 = \text{Ag}_2 \text{I} + \text{I}$ . The iodine is taken up by the silver plate at the back of the sensitive film. To develop the picture, mercury vapour is caused to condense on the sub-iodide, and leave

the iodide intact. Amongst some pictures which Mr. England has kindly brought, we have an instantaneous view of New York Harbour, taken about 25 years ago; and I doubt very much whether there are any wet plate instantaneous pictures equal to that; from age it has become a little bit tarnished, but otherwise it is a most perfect picture—the size is about 5 in. by 4 in. I have a transparency taken from this, and one from a negative, also in the possession of Mr. England. This last is a portrait of Daguerre, taken by himself. This is interesting as showing one of the very earliest daguerreotypes known.

The next process is the Talbotype process. In Talbot's original process, chloride of silver formed the basis, and from that sprung our silver printing process of the present day. But the great improvement he made was by the introduction of iodide of silver. I may mention that he introduced this in January of the same year in which Daguerre introduced the daguerreotype process in France, namely, in 1839. The outline of the talbotype process is as follows:—First of all, he gave a wash of nitrate of silver to plain paper—some papers answered better than others—this he dried, and then washed over it the iodide of potassium, so forming iodide of silver, then dried the paper, and again washed over it the nitrate of silver. Such a paper was found sensitive enough to take camera pictures. But how about the development? Curiously enough, the development of the talbotype picture was discovered in an independent way by the Rev. J. B. Reade. He was practising with the solar microscope, and copying certain objects. One afternoon, having given his paper, which he had washed over with gallic acid, a short exposure, he was obliged to leave it for the night; next morning he found that his image was fully developed. That gave him the idea of the development of what was called the latent image. Talbot introduced this mode of development into the calotype process. This calotype process was the subject of litigation, and the claims of the Rev. J. B. Reade to be the discoverer of the gallic acid development was disputed. I do not wish to enter into the legal question as to who was the discoverer, but my own opinion is Mr. Reade should have the credit which belongs to the discovery. From the negative pictures so produced, an unlimited number of portraits would be made by what we call the ordinary silver-printing process. A daguerreotype, on the other hand, could be only reproduced by electrotype, and

Mr. England has kindly lent me such a reproduction, which can be examined afterwards. I propose, however, to show you how Talbot was able to make a picture on paper. I intended to have taken a camera picture by the process, with the aid of the electric light, but I find it will take up too much time. I have here a negative with some talbotype paper upon it, prepared as described. I will expose this to the light from a bit of magnesium wire, and then will develop it in the way in which that development was practised in the old time. I have a solution of gallic acid, which I place in a little dish, and with it will mix a solution of nitrate of silver and acetic acid. The acetic acid is meant to retard the action of the gallic acid, to prevent the reduction of the silver before the development takes place. I should say the usual method of using the paper was as follows:—A final wash of gallic acid and silver nitrate was given it, and it was then exposed while damp in the camera. This is what I intended to do, but the minutes steal on us so very rapidly, that I have been obliged to leave out the wash of gallic acid and silver, and to give it a rather longer exposure behind a negative, and thus I shall produce a positive on development. The undeveloped picture is now placed on this piece of glass, and now I proceed to develop it. The glass is placed on



STAND FOR DEVELOPING PAPER PICTURES.

a stand, and the light from the lantern, after passing through orange glass, is allowed to illuminate it. The lines begin gradually to appear, and they must now be visible to you all. I continue brushing over the picture the solution of gallic acid and nitrate of silver, with acetic acid, and it becomes still more visible. A paper process is a most fascinating process, because you can dab about with your brush and do exactly what you like; it is not like the gelatine plates of the present day, which you have to leave to come out mechanically. With paper, if you want to bring it out a little better

detail in one place there, you can dab it out; and if you want to keep it back, you can put a little water over the place. There is no process like the paper process to please an artist; not that I profess to be an artist, but, belonging to the Science and Art Department, I have a sort of art instinct, I suppose. I think you can see that the image is very fairly out now. In the old days, I dare say it would be considered passable for a beginner, not that I am a beginner, because I practised it in India; but it is a long time ago since I did so. So much, then, for the talbotype process. Now, what is the meaning, I would ask you, of that development. It is a curious thing that a small exposure to light should cause an image to appear. I will ask Mr. Woods to throw on the screen something which perhaps will illustrate how development arises. This morning I was in my laboratory, and I saw lying on the bench a feeble negative which I had badly developed, and which I had fixed with hypo-sulphite of soda. On taking it up, I found the salt had crystallised over the surface in a most beautiful manner, and I do not think I could point out to you anything which would give you a better idea of what development is than those crystals whose images you see on the screen. When you have silver precipitated from a solution by any means whatever, you have it always in a crystalline form, and as all crystals possess polarity, so crystals of silver possess polarity; and where one silver particle is deposited, there another silver particle will deposit, exactly in the same way as those crystals of hypo-sulphite of soda follow one another in regular course in those beautiful feathers. Thus, then, I look upon it as a physical development; we have a crystalline action going on during development, and nothing else. The iodide of silver is altered into sub-iodide, and this, like the pole of a magnet, attracts the precipitating silver, and from that time, where the first crystals of silver are deposited, other crystals of silver are deposited. That is what I call physical development.

Now, there is another kind of development which some call chemical development; and here I differ from some of my brethren who live on the other side of the water, in Germany who have chosen to name as chemical development something quite different to what is my idea of chemical development. I say chemical development is only a development which is shown by a change in the colour or material of the substance acted upon, and not by

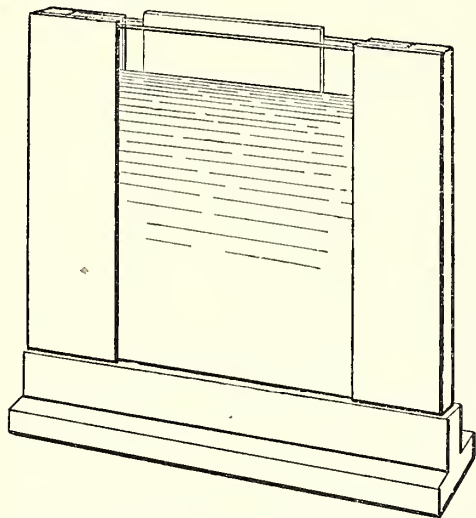


a building-up process, such as we have had before us. Now, I have something which I hope will show you what I mean by this chemical development. I have here a picture, which has been printed on nitrate of uranium; I am going to use simply silver nitrate for a developer. I do not want a reducing agent in the developer in this case, for since the uranic salt is reduced to the uranous state by the action of the light, we shall have a picture formed of silver oxide, because the uranous salt will reduce the nitrate of silver to the state of oxide, and that of itself can be reduced afterwards to the state of metallic silver. This paper was exposed, just before you came to the lecture, to the electric light behind a negative. There is an outline of it now, but when I apply the silver, you will see that it springs out into vividness. It has been rather over-exposed, but this I do not mind, as I merely wish to illustrate a principle. The whole of that picture is formed by silver oxide reduced by the particles of uranium nitrate which have been acted upon by light, and by nothing else. The silver oxide reduced is an exact equivalent of the uranium salt which has been altered by light. That is what I call chemical development, and I know no other meaning for the term. It is impossible, except where you have a change in a large amount of the material that is acted upon by light. I hope I have made you understand the difference between this development and the development you saw just now. The gallic acid, in the one case, reduces the silver solution to the state of metallic silver; and, in the other case, the uranous image itself reduces it to the state of silver oxide; but still that silver oxide was only equivalent to the amount that had been acted upon by light, and nothing more. I have here a wet plate prepared. I dare say most of you know what a wet plate is, though some of you may not if you only began photography when the gelatine process came in. To such, I suppose, a wet plate is as much a matter of novelty as a daguerreotype is to many who know what the collodion process is. I will ask you to bear with me, however, while I produce the picture, because I want to show you a use of the electric light. Of all the recent aids to photography, the electric light is one of the most powerful, because with it you can photograph by night or by day. In fact, in some of the advertisements I have seen it stated that they prefer to take portraits by night; I do not know why, but in a country

town I saw an advertisement in which they said distinctly they preferred to take photographs by night, as it was more convenient. [An engraving was focussed on the camera-screen, and the wet plate exposed for twenty seconds.] A short exposure will do for this. Now I will try to show you the development on the screen. I hope you will see the crystalline action taking place before you, and the image built up by the crystals as they deposit, gradually coming out on the screen. A cell containing ferrous sulphate in solution, and a small quantity of glacial acetic acid, is focussed on the screen. The plate of sensitised (and now exposed) collodion is fairly transparent. After placing a piece of yellow glass in front of the lantern, the plate is immersed in the cell, and the image is seen gradually being built up.

There is another mode of development which our friends across the water have chosen to call chemical development, though I cannot agree with them, and that is the method which is called alkaline development. I dare say I could very rapidly demonstrate that to you. The *rationale* of the alkaline development is that when you have a strongly oxidising agent in the presence of an alkali and a silver compound, solid or in solution, then you have the last reduced to the metallic state. Such an oxidising agent we have in the pyrogallic acid, and the alkali generally used is ammonia. Now, this kind of reduction is evidently useless unless it can discriminate between a compound which has been acted upon by light and one which has not. When pyrogallic acid is used in order to make this discrimination, or, in other words, in order that those parts acted less on by light may alone be reduced, something more has to be added, which is usually a solution of a bromide of an alkali. This restrains the reduction inducing the change to take place in the part acted upon by light. I may say that without a restrainer the tendency is for the exposed parts to be first reduced, but the action extends to those which have not been acted upon by light. It has been usually said that alkaline development is only available for bromide of silver, and until recently I dare say that was the case, or rather it was not the case, but it was thought to be so. I hope on a future occasion to show that iodide of silver is as amenable to alkaline development as bromide of silver, although not so rapidly, and that chloride of silver is very amenable to alkaline development, giving in fact most beautiful pictures. The plate I am going to expose now is a bromo-iodide plate. I have shown

you this form of it, simply because it is transparent. I have here a negative, and the ready prepared sensitive plate behind it. Now I expose it to the light from the magnesium wire for a few seconds. I will take a cell, in which I will place some of the alkaline developing solution. The pyrogallic acid and bromide are mixed, and the ammonia is ready for adding. I mix a small portion of this latter with the pyrogallic acid and bromide—the bromide, remember, being for restraining purposes. I place the plate in the cell, which is



CELL FOR DEMONSTRATING PROCESS OF DEVELOPMENT.

seen in focus on the screen. The picture is one of Mr. England's beautiful statuary studies, and you can see the outline of the bust gradually appearing. That, I say, is another case of physical development.

Now, I want to show you why I say it is physical development. I throw on the screen a slide, which is a picture of a young lady, seemingly cut in half, part of her figure being intense, and part not intense. This difference in intensity was produced by exposing a plate behind a negative, and then before development, coating a portion of the plate with bromide of silver. The top layer thus had no exposure whatever, and yet you see where the unexposed film is, there we have the picture very much denser than in the case where there was only the one film. This shows that here we have a case of physical development, for the image is built up from the film itself, being partly fed, as it were, from the film which had received no exposure. There is thus crystalline action taking place in the film, just as much

as there was in the silver reduced from the nitrate of silver. I want you to understand why I object to the words chemical development, when we are talking about alkaline development.

There is another mode of development, which is now very much in vogue, and that is with ferrous oxalate. In this case we have an organic salt of iron in the ferrous state, which is capable of reducing silver bromide, iodide and chloride, to the metallic state, whilst itself is reduced to the ferric state. That was a development which also required a restrainer. If I had had time there were several more experiments I should have gone through, but I must omit them. There is, however, another kindred developer, which I think is one of the most recent advances in photography, about which I am supposed to be lecturing. I speak of it with great tenderness, because it is my own child. I have now got an iron developer, which is capable of being used without any restrainer whatever. I call it ferrous citro-oxalate; it is rather a long name, and some of my audience may not understand it, but I will tell you how it is made. You take a solution of citrate of potash, and then you add ferrous oxalate to it, till no more will dissolve, the resulting compound is, probably citrate of iron, but in a stronger form than is usually found, and much more energetic than that form which was recently recommended by Dr. Eder, to whom I shall have to refer more at length presently. I propose to use some of that same paper which I used just now. Its use for the purpose I have in view is a novelty. This paper can be developed by the alkaline method, or by the ferrous oxalate method, or by the ferrous citro-oxalate method; it is an excellent paper, and was prepared as I described about two years ago at the Photographic Society, before the gelatine papers came into vogue; it gives a very clear picture, and I dare say that you will also see that it gives very satisfactory negatives. I expose a piece of the paper behind a negative to the light of the magnesium wire again. The negative is used in this case was kindly lent me by Mr. William Bedford. It is rather a dense one, and requires longer exposure than I should have given to a thinner negative. The exposure is now given, and on withdrawal from the frame, it apparently is a perfectly blank piece of paper. [The paper was wetted and placed on the developing stand already described, and brushed over with ferrous citro-oxalate without any

bromide being added. The lantern was covered with yellow glass, and the light of the disc thrown on the paper.] You see it is beginning to develop; see how beautifully it comes out. This, I say, is a novelty in photography, for here we have an iron developer which needs no restrainer, and a paper which can be developed by an energetic developer. I think I may claim that as an advance over the calotype process.

I must defer what I have to say on other developers to the next lecture; but before I close, I am gratified to be able to bring before the meeting some very early calotypes, taken by my distinguished friend, Mr. James Glashier, who is President of the Photographic Society, and who has worked at photography from its very earliest beginning. These are some of his beautiful

fern impressions he got with the talbotype, and printed afterwards. I will ask the members to look at them, as being early examples, both of talbotype and calotype; the one being developed pictures on iodide of silver, and the other being the printing process of the negative on chloride of silver paper, such as Talbot first introduced. I have also to show you Mr. England's developed daguerreotype. I will undertake to say that under the circumstances it is a very good daguerreotype indeed. Of course a lecture-room is not the place to show all the niceties of the art, and, in fact, it is very difficult to demonstrate before such a large audience, but I hope those experiments which, luckily, have all been successful, will at any rate have afforded some instruction to the junior members of the photographic world.

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## LECTURE II.--DELIVERED FEBRUARY 6TH, 1882.

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At the last lecture I introduced to your notice the ferrous citro-oxalate developer, for which I claimed the advantage that it was able to work without any restrainer whatever. To-night, I propose to bring before you another developer, which is also able to work without a restrainer; but before I do that, I should like you to take note of an improvement, which has been lately introduced by Mr. Berkeley, in the ordinary alkaline developer. With the pyrogallic acid is mixed four times the weight of sulphite of soda. The action of this sulphite, apparently, is this—the sulphite of soda absorbs the oxygen with greater avidity than does the pyrogallic acid, thus leaving the pyrogallic acid free to do its work, and, consequently, we have a developer which remains uncoloured for a very long period indeed. I hold in my hand a bottle which was presented to me by Mr. Berkeley,

some time ago, which I read was made up on October 13th, 1881. This contains four times the quantity of sulphite of soda that it does of pyrogallic acid. Here is another bottle of pyrogallic acid, made considerably later—some time in January—and you will see the difference in colour between the two. The one is slightly yellow in tint; the other, a deep muddy brown. I consider that this introduction of sulphite of soda into the developer is one of the most remarkable improvements in alkaline development, and I hope that those practical photographers present will not hesitate to try the formula which Mr. Berkeley has lately published.

I now propose to show you the practical use of the developer to which I referred when I commenced. It is a new one, but has not been used to any very great extent, I am afraid, on account of the high price

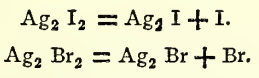
it used to fetch. I refer to hydro-kinone; the first quantity I bought cost me 12s. a drachm, but, I am happy to say, it is now only 8s. an ounce, and one grain of it is as active as two grains of pyrogallic acid, for it is a much more powerful absorber of oxygen than pyrogallic acid; its main advantage, however, is, that you are able to use it without any restrainer. You can even develop chloride of silver without adding any soluble alkaline haloid to it, which photographers know is essential when using even a very weak pyrogallic and alkaline development. To illustrate this, I have an opal glass plate which is covered with a film of collodion containing chloride of silver. Until quite recently, this was a film which it was almost impossible to develop by the alkaline or iron methods; but, thanks to Dr. Eder, we are able now to develop chloride of silver exactly in the same way as we can bromide of silver. To save time, I gave the plate a short exposure just before the lecture. In this cell I have now simply hydro-kinone and ammonia, and I think you will see that it develops the plate without the slightest trace of fog. I have taken an opal glass as the background, so that you will be better able to see the result; it comes out very gently and gradually. Thus you have a practical demonstration that this new developer works without any restrainer, even when such a troublesome salt as silver chloride is used. Not having any restrainer, it is able to give a better detail, and allow a shorter exposure in the camera than if the ordinary alkaline developer be used. This development is applicable not only for collodio-chloride, but for collodio-bromide plates, or for gelatinobromide plates—in fact, any plate with which you work, even iodide. [The perfectly developed image was then shown.]

I promised last lecture that I would show you how very easy it was to develop iodide of silver with either the alkaline or the ferrous oxalate developer. You saw in my last lecture how we could develop the iodide with silver and gallic acid, but it becomes a very different thing—at least it was always so considered—when you have to develop a plate containing simply iodide with nothing but an oxalate developer, such as I have here. In this frame I have a paper which is coated with pure iodide of silver, not a particle of bromide or chloride in it; I will give it a slight exposure, and I propose to develop it on the screen before you. I will simply immerse it in water, and use some of the same ferrous citro-oxalate which I introduced to your notice last week. It will be

apparent with what facility the iodide of silver can be developed. The paper, where viewed in the yellow light, is apparently colourless, although really it is yellow. If everything be correct, you will see that we get an image developing out rapidly, which is formed of pure metallic silver, reduced from the sub-iodide at first, and then fed, as it were, from the adjacent iodide. [The picture was fully developed.] We now have a practical demonstration that you can develop iodide just as easily as you can bromide, which is a desideratum when you come to consider the composition of gelatine plates, with which we may have to deal more fully in subsequent lectures. Having fulfilled my promise with regard to this, the next point I wish to call the attention of the meeting to is the action of sensitisers. I should like to explain to some of you who are not initiated in the mysteries of photography, what a sensitiser is. I will throw a diagram on the screen, and then you will be able to understand better what I mean. When you have chloride of silver, for instance, exposed to light, you have a new compound formed, which is called sub-chloride, or argentous chloride ( $\text{Ag}_2 \text{Cl}_2 = \text{Ag}_2 \text{Cl} + \text{Cl}$ ), and chlorine liberated. This chlorine is a very obstinate thing to eliminate, if you do not give it something that can take it up; for instance, if you place perfectly dry chloride of silver in vacuo, without any trace of organic matter present, you will find, if it is exposed to brilliant sun-light for months, you get no darkening action. If such a white powder was submitted to you, to test by its darkening, you would say at once that it was not chloride of silver, because it was not darkened, one of the tests of chloride of silver, amongst chemists, being, that it shall darken in the light. Here I have a little bulb of it which was prepared, dried carefully, and sealed up, the vacuum being made by means of a Sprengel pump. This tube has been exposed for months to light, and it is as pure a white as the very first day it was put into the bulb. Another experiment was made at the same time; a bulb was prepared, but in using the Sprengel pump, unfortunately, as I then thought, a small globule of mercury got in the vacuum, and was sealed up with the chloride; the consequence was, that the chloride of silver immediately darkened; although the mercury was not in contact with the chloride of silver, the chlorine flew to the mercury, and formed chloride of mercury. This is an instructive experiment, showing that merely in the presence of something that will mop up the

chlorine, chloride of silver will darken. Here is another darkened bulb of chloride of silver, which was sealed up, not in *vacuo*, but in hydrogen. Now, hydrogen, as you are perfectly aware, can combine with chlorine to form a gas, which we call hydro-chloric acid, so, when the chlorine was in the presence of hydrogen, it combined with it, instead of returning to re-combine with the sub-chloride of silver. On the screen is a diagram showing these reactions of the two other haloid salts of silver. I have already shown you the diagram of silver chloride, and its splitting up by light.

Silver iodide splits up into silver sub-iodide and iodine.



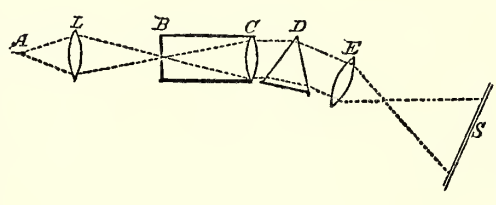
Silver bromide, when exposed to light, splits up into silver sub-bromide and bromine.

Now, in order that there shall be a ready darkening of either of these, you must have something which will absorb the iodine or bromine (or in the case of the latter, allow it to escape), whichever you expose to the light. Now, the image which you just now saw developed on the iodide, was, before development, precisely in the same condition as the darkened image on the chloride; it is a matter simply of degree. Of course, if you took a few shot, and hid them in a bushel of flour, you would not know that there was anything black in the flour; in the same way, if you alter two or three particles of iodide into sub-iodide, or chloride into sub-chloride, you do not notice it, because they are so mixed up with the particles that are not altered. It is these little altered particles that are the nuclei for the developed image. In order to demonstrate practically the use of sensitisers, I have prepared a sheet of paper, a quarter of which has been washed over with that vulgar beverage, beer; another quarter with potassium nitrite, and another quarter with gum; the fourth quarter has nothing on it. Now, all these three are—but in greater or less degree—absorbents of iodine and bromine, and you will see, when I expose the paper and develop, that there is a decided increase of sensitiveness where those substances have been applied. You may say, "according to what you have said already, the particles not coated with anything ought not to develop," but you must recollect that we are in contact with air, and air contains moisture, and if you have chlorine, for instance, in the presence of

moisture, light is able to split it up into hydro-chloric acid and oxygen, so that, in the case of a paper like this, you have a sensitiser present, but only a feeble one. This paper is the bromo-iodide paper that I introduced to your notice some little time ago. I have marked on the different quarters of it what is the sensitiser on each. I will brush it over with this ferrous citro-oxalate developer, and we shall see if there is any difference in the rapidity of coming out. The part coated with nitrite in coming out very rapidly, it has a very inordinate affection for iodine and bromide, the vulgar beverage beer does not seem to be doing its duty as it ought to be; now the gum is flashing out; now the beer is coming. You see the nitrite came out first, then the gum, and then the beer, finally that in which the sensitiser was merely the air and the paper, and you will see, when the picture is finished, there is a vast difference in the amount of development. If there had been no moisture in the atmosphere, if it had been exposed in dry air, there would have been no action whatever where it was not coated with some sensitiser. Here, then, we have a proof that a sensitiser is necessary in order to give the greatest possible sensitiveness, and I hope that this will explain to you what I shall have to allude to further on.

I next have to call into use the spectrum. Here we have it on the screen, and I have produced it by the same arrangement of apparatus as if I were going to use it for photography. You will see that we have a tolerably clear spectrum. We have the light,

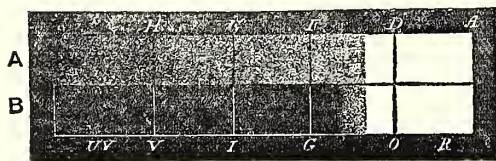
FIG. 1.



A, and a lens, L, to throw the image on the slit B, and then the lens, C, to make the rays parallel, then a single prism, D, then a photographic lens, E, which focusses the spectrum on the screens. Now I want to point out to you not only that we have red, green, yellow, blue and violet rays, but we have rays beyond the violet also which we cannot see, but which by an artifice I shall be able to show you. For instance, if I place this card on this screen, you see we have a vast extension of the spec-

trum beyond the violet, but if I take it away, it is absent. The reason of that is, that I have brushed over the card a solution of sulphate of quinic, which lowers the wave lengths of the ultra-violet rays, making them visible. I was anxious to bring this before you, for this reason, that it is the principal part of the spectrum which is useful to photographers, though I do not believe they are aware of it. When we expose one of these haloid salts of silver to the spectrum, it behoves us to know what part of the components of light it is that acts upon this haloid salt. Now, a very simple way is, of course, to place a film containing the haloid salt in the spectrum. But what I want first to point out to you is, that we must go upon scientific principles in dealing with the facts that come before us, and the main principle involved is the principle of work. When you have what you call light radiating from a source, be it the sun or be it a gas flame, it is only when its radiant energy is stopped or absorbed that you are able to get any work out of it all; that is to say, supposing you have a transparent glass plate, you know that the light, as you call it, passes straight through the plate, without leaving any very visible effect on the glass. But if you have a red glass, why does it appear red? Simply because a part of the rays have been stopped; but what becomes of those rays that are stopped? they must take one of two forms, or rather, the work they do must take one of two forms. The work they can perform may be shown by the heating the glass, or else the energy must be exhausted by doing chemical work upon the substance on which it acts. The effect then, is this; if you have an haloid salt of silver, the principal part of the energy which is radiated, and which is absorbed, does chemical work, and it is only those regions of the spectrum which are absorbed which are capable of doing chemical work. I cannot show you a better example than I have upon

FIG. 2.

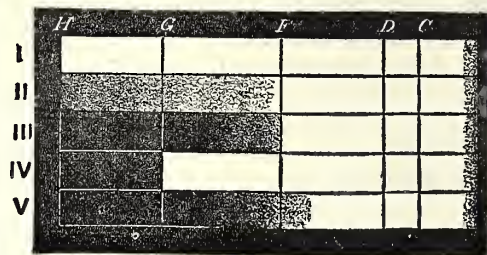


the screen. The second part of the slide shows the whole spectrum, taken with a substance which I shall be able to show you by

and-bye. You see the darkening caused by the light; at the far end we have the ultra-violet rays, and at the other end we have the red rays. In front of the slit of the spectro-scope was placed a cell of bichromate of potash, and you see it cuts off, not only the blue and the violet, but a part of the green, and leaves the red and yellow intact (B, Fig. 2).

Now, photographers know that those beautiful prints that go by the name of carbon prints depend for their manufacture on the fact that bichromate of potash is altered by light in the presence of organic matter. Here we have the spectrum taken on carbon tissue, in which you will see the absorption exercised by bichromate of potash exactly coincides with the work done on the bichromate (A, Fig. 2); notice that the part of the spectrum which is impressed ends exactly where the bichromate absorption begins. I think that is a very excellent illustration of the work done by radiation. I propose now to pass two or three films through the spectrum (I., Fig. 3), to see what kind of work we may

FIG. 3.

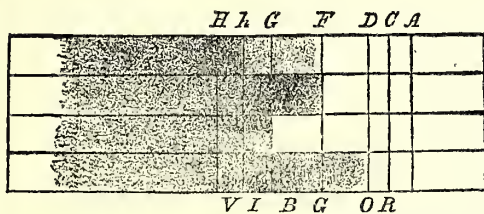


expect to be done with them. First, we have a film of chloride of silver (II.), and you will see that the violet part of the spectrum towards the yellow is subdued, whilst the other parts pass through. Next, we have a bromide film (III.) in which you see some parts of the spectrum are cut off which before were visible. Next, I take iodide (IV.) where you see the violet is cut off entirely, leaving a trace of blue, which was not the case with the bromide. Here, again, we have the bromo-iodide (V.) cutting out the blue, going right into the green. That is interesting, because I propose to show you next the fact that the absorption coincides with the work done on the films themselves.

I have here a board with four strips of paper upon it. The first coated with chloride of silver, the second with bromide of silver, the third with iodide of silver, and the fourth with bromo-iodide of silver. I will expose each of them for twenty seconds, to the spectrum, and

develop them before you. In order to recognise the parts acted upon, there are strings put across the different parts of the spectrum. [The exposures were made, and the strips damped and placed on the developing board.] I brush each strip over with the ferrous-citro-oxalate developer. [The prints developed rapidly, the chloride taking rather longer than the others to appear.] The chloride sometimes takes a little longer to develop, and I ought to have given it a little longer exposure, because it is not quite so sensitive as the other salts. Here are the four spectra (Fig. 4). The maximum

FIG. 4.



sensitiveness of the chloride, A, is about the line H on the spectrum. The iodide, C, goes as far as G; the bromide, B, half-way between G and F, and faintly extends down as far as B; the bromo-iodide, D, extends as far as F in the spectrum. I think I can show you this more directly by photographs taken in the spectrum, in a more accurate manner than is possible in a lecture experiment. When I passed the different silvers through the spectrum, I only passed the haloid salts in the state in which they are usually prepared photographically, but now I wish to show you how different coloured salts of silver can be obtained. Let me take bromide, for instance. Here you have the ordinary form of bromide, such as you saw developed on the screen—the red or orange bromide. By boiling it, as you do, with gelatine emulsion, you can change the molecular condition into a gray blue form, such as you see here. From what I have told you of the principle of work and absorption, you will be quite prepared to learn that these particular forms are sensitive to different parts of the spectrum; so they are, but their maximum place of sensitiveness is but very slightly changed; that is a point worthy of attention. Again, we have two forms of chloride, the ordinary form, which, as a rule, is decidedly yellow by transmitted light; and the other is the blue molecular form, which is got by boiling. Once more, we have the iodide in the yellow form, and also the blue form. Now, I will

show you photographs which were taken to show the maximum of the different haloid salts (Fig. 5, p. 14). The first one is the red form of chloride (No. 1), and you see that the maximum sensitiveness is half-way between H and A in the violet part of the spectrum; if we go to the boiled chloride (No. 2) you see it has the same place of maximum intensity as the orange, and that the intensity is very great as far down as the yellow line, D. We next come to the red form of bromide (No. 3), and we see that its maximum place of sensitiveness is half-way between G and F. When we come to the blue form (No. 4) we have an immense extension towards the red, but still it retains nearly the same place of maximum sensitiveness between G and F. Next, we have the yellow form of iodide (No. 5), and it shows that it ends sharply at G. There is no spectrum impressed beyond G. In one case where I gave it a very prolonged exposure, I got what is called a reversal of the image, but still the iodide spectrum is cut off at that particular point (No. 6).

The next spectra are exceedingly interesting—to me at all events—and I should like them to interest you. They represent a new form of molecule. I believe very few people know anything about them. The peculiarities of the mixtures were discovered by me, and a paper about them sent to the Royal Society a very short time ago. The type of the new molecule is this: it is not a combination between iodide and bromide in the ordinary acceptation of the word, that is to say, it is not  $\text{Ag}_2 \text{Br}_2 + \text{Ag}_2 \text{I}_2$ , or not simply one equivalent of each of bromide and iodide of silver added together, but an absolute combination,  $\text{Ag}_2 \text{Br I}$ , or a double molecule, which has been formed, and on which the spectrum has a totally different effect. You will see (No. 7) that, instead of having the maximum intensity at G, its maximum is far into the green, and it has a minimum about G. In the same way another molecule is formed by a combination of molecules of chloride of silver and iodide of silver, and that, too (No. 8), has no maximum about G, but has a minimum there, which is the place where the maximum sensitiveness is found in the ordinary iodide of silver.

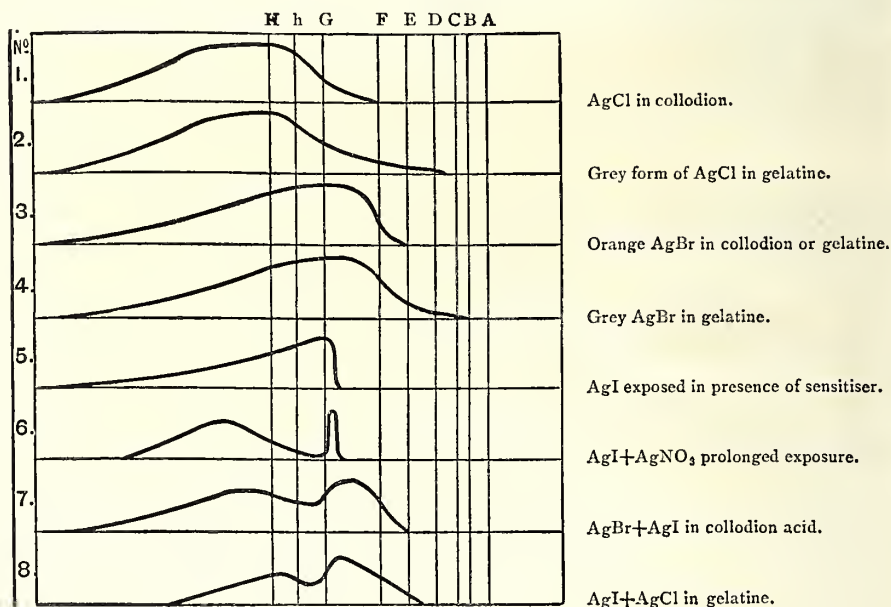
I will try and explain how these last curves are produced; if you take iodide and bromide of silver together, and expose them to the spectrum, what happens is this; first of all iodine and bromine are liberated. What becomes of the iodine and bromine? The bromine immediately attacks

the sub-iodide of silver, and forms a new molecule,  $\text{Ag}_2 \text{Br I}$ ; the bromine undoes the work of the iodide as fast as it is done, so that we have, in the place of maximum intensity of the iodide, the least work done. In the same way with the chloride. The chlorine liberated from the chloride undoes the work which is done by the iodine; the consequence is that, in the place of maximum intensity of the iodide, we have a diminution of intensity in the case of the double salt; in other words, the dry bromo-iodide of silver is less sensitive for the spectrum about the part G than any other part of the spectrum to which it is sensitive. In order to prove that, I will narrate a little experiment which was carried on by myself. Chloride

of silver was absolutely blackened in the light, and sub-chloride was formed; then it was treated with iodine again, and it become a buff colour. When this new molecular form was placed in the spectrum, we got exactly the same result as we do here, showing that we have a new molecule of chloro-iodide of silver. I think this will very likely throw a great deal of light upon some of the phenomena which are met with in ordinary dry-plate work.

Now, I crave your attention to one thing. You may ask if bromine always undoes the work done on the iodide. The fact is, that it does not, if you have free nitrate of silver present; since this salt is able to take up the iodine and bromine, therefore the bromine can-

FIG. 5.



not act on the sub-iodide of silver; it leaves it there, and you have the impressed spectrum totally different; in fact, the bromide and iodide spectrum are superposed one on the other. There are a great many facts I could show you to prove this. We come to the conclusion then, for sensitiveness, you must have a sensitiser present. In gelatine plates, you may say that gelatine is a sensitiser, but it certainly is a very feeble one; anyhow, if you want to get sensitiveness in a plate, you must have a sensitiser present which will mop up, not only iodine, but bromine. When this is the case, bromine cannot go and destroy the work done on the iodide.

Before concluding this part of my lecture, I may also say I have found that the printed

image and the developed image have precisely the same characteristics. Thus, if you get pure iodide of silver, you get the termination of both the printed and developed spectrum close to G. A curious thing with regard to iodide is this, if you have the smallest trace of impurity in it, it is immediately shown in the spectrum by a prolongation below G. With such a tail present in a spectrum on silver iodide, you might tax the chemist with having given you iodide which is not pure.

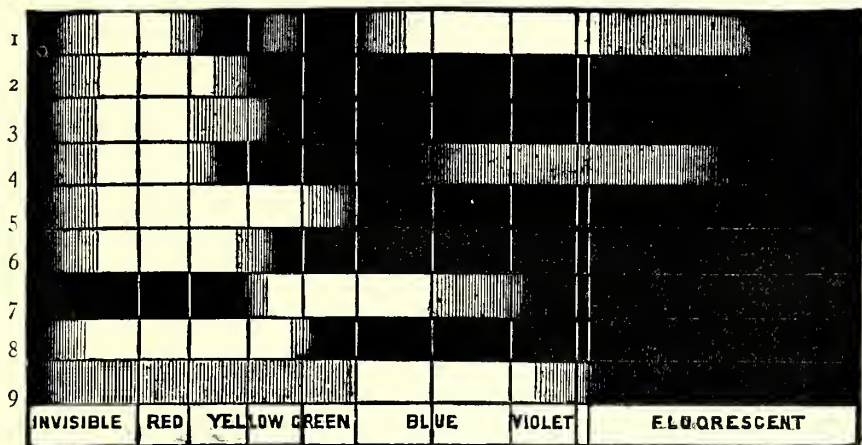
Now there is one point that has exercised the minds of a great many photographers, and that is the illumination of their dark rooms; and I hope I may be excused if I go over what may be apparently well trodden



ground, but I believe that there are many here present who have no absolute certainty as to why they are using certain glasses to glaze their developing rooms. I want to show photographers the absolutely safest light they can use in developing their pictures. Here we have a spectrum, and beyond it you see the fluorescent rays. I will ask Mr. Woods to pass through the spectrum one or two glasses. First of all, we will take ruby glass (No. 2), and you will see that when the spectrum is very bright a certain amount of blue light comes through the glass; I can see a trace of yellow, and a trace of green. Now I will take the yellow glass; here is one which photographers are very fond of, but I dare say you will see that

there is a great deal of blue light comes through that. That was the ordinary glass used for photographic dark rooms, within the last half dozen years, and people were perfectly content if they glazed their rooms with it. But there are yellows and yellows, and I will show you the difference between two. Now we have deep orange (No. 5), which you see cuts off a great deal more light. The next (No. 6) is a stained red glass, which cuts off the green too. Now there is one combination which I wish to show you, because people often complain that their photographic studios are not safe as to light, and that they use ruby glass and get foggy plates. I have great doubt about fogging bromide plates with proper red glass, where ordinary precautions are taken,

FIG. 6.



1. Cobalt glass.  
2. Ruby glass.  
3. Chrysoidine.

4. Magenta.  
5. Flashed orange.  
6. Stained red glass.

7. Bottle green.  
8. Aurine.  
9. Quinine.

though not with the ruby glass which lets blue light through. If people would only use the spectroscopy with a strong light, they would very soon see where their glazing is at fault. Now, I will throw on the screen the light through a piece of blue glass (No. 1), and I think you will see that there are bands in the red and yellow; there is plenty of blue coming through and some green. Now, I will ask Mr. Woods to give us a combination of stained red and blue; you see a red line and nothing else. If photographers want to be absolutely safe, let them glaze their studios with cobalt glass and stained red, and they will get nothing but the light of that particular refrangibility, which I will warrant is totally unable to affect any gelatine plate, of the ordinary type, at all events. You may glaze and glaze with ruby,

but you will never get rid of blue light entirely. Of course it diminishes with every thickness you take. If you want to use ordinary plates, which are not so sensitive that you cannot look at them, my advice is to use a combination of stained red (No. 6), and ruby glass (No. 2), which will give you a comfortable light to work in, for it cuts off the blue, and leaves the red in a brilliant patch. Those that are using that combination ought to have nothing to fear; but if they still fear, let them use a combination of cobalt glass (No. 1) and stained red glass (No. 6), and then they will only get the colour of that narrow strip of light which you saw just now. I should like to show you the green glass in the spectrum (No. 7), that you may judge what kind of light gets into it. It was at one time seriously recommended

as an admirable thing for not trying the eyes, and for being safe to use in the developing room. A combination of red and green is a fairly safe light for iodide plates or ordinary plates, but not for gelatine plates, which are extremely sensitive. Next we come to a series of pretty colours, which may be very useful to us. Here is the spectrum of magenta (No. 4); the yellow and the green are cut out entirely, leaving the blue, violet, and orange. Now I will try aurine (No. 8) and chysoidine (No. 3). Here you see the blue is gone entirely. Some have said that the ultra violet rays go through aurine, but I will leave it to you to say whether they do or not. There is no trace here of the ultra violet rays when I apply this card with the sulphate of quinine on it. They should appear if there were any. We have next a combination of magenta and aurine, which is a perfect red light, and is very good indeed for the photographic studio. I think I may say, without a breach of confidence, that I believe a certain "ruby medium" in the market is made according to the directions that I gave some time ago. You may ring the changes of combinations of these glasses; you may have scarlet and aurine, or magenta and aurine, and either one or the other will give you this red band only. If all other means fail, the photographer may use the ferrous oxalate developer. You will see that it cuts off the blue light at all events. I should not at all mind developing a plate in such a light as that. In fact, you may bring the most sensitive plate out into a white light, when developing in a dish, with a covering of ferrous oxalate over it. I hope that, having seen these spectra, you will lay to your heart what I have been saying to you about the glazing of your dark rooms. I thought this was a subject that I ought not to pass over without some reference.

In 1874, we had a most astonishing discovery made, and that was, that by dyeing a film of sensitive collodion you were able to get an increased action by the spectrum. In common with others I took up that subject and investigated it, and I wish to draw your attention very briefly to it to-night, because I think it is one of the advances made in photography which ought not to be passed over. If you take one of these aniline dyes, such as a blue dye, and expose it to light behind a piece of black paper, with an aperture in it, such as I have here, you get an image on the dye, such as you see. What is the meaning of that? The meaning is that the dye is oxidised,

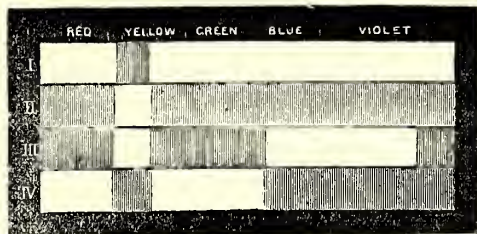
for if you apply an oxidising agent you get the same result. Dr. Vogel found that if you dyed plates with some of these fugitive dyes—they were all fugitive to a great extent which he used—he was able to obtain an extension of the impressed spectrum exactly in those parts of which the dyes absorbed, and he introduced the term optical sensitiser to describe the fact. Now, I am going to quarrel with that expression, because he explains it in this way; he says, in effect, that the sensitive aniline dye is able to take up a vibration, and to direct it to something else; in other words, that when light has done all it can in endeavouring to bleach a dye, that its period is transformed, and it does something else on the silver salt which is in contact with it. Well, that is not a philosophical way of looking at things, because if you could only arrive at that principle, you might just as easily arrive at the principle of perpetual motion, which is a thing which I am not prepared to admit. Now, I honestly say, that for a long time these experiments staggered me, and the arguments Dr. Vogel brought forward seemed fully to justify his term of optical sensitiser, as applied to the dye stuff, but eventually I was able to come to a different conclusion, and that conclusion I wish to put before you. If you have a substance which is oxidised in the presence of an haloid salt of silver, what do you expect? You expect that the haloid salt of silver would be reduced. If you place pyrogallic acid in contact with the haloid salt of silver, and help it to be oxidised by ammonia, you expect that the haloid salt of silver will be reduced, and I lay the action of the dye to precisely the same principle as the pyrogallic acid, which helps to develop the image; in other words, the oxidation of the dye causes a reduction of the bromide of silver or iodide of silver, as the case may be, and simply provides a nucleus on which development can take place. I wish, however, to point out that Dr. Vogel has an objection to my explanation. He says, "Oh, but you require time to bleach things, you require time to alter them." So you do; you require time to blacken the chloride of silver, nevertheless the slightest exposure to light begins the change in it, and so the slightest exposure to light begins the change in the dye, and on this principle, of course, the action of dyes upon sensitive films can readily be explained.

I have got behind the screen three pieces of sensitive bromide paper, one dyed with blue dye, and another with eosine, the third

pure bromide of silver without anything. I propose to develop those on the screen. I must give this rather a longer exposure than last time, because blue dye takes away the sensitiveness to a material extent. You can see the colour, it is somewhat of a lavender grey, which no doubt will show that it absorbs exactly in the same position where the extra portion of the spectrum is developed. In the eosine, I dare say you notice a peculiar dimming of light about the green; this is a very fluorescent dye, and it is in that position where we shall expect the action to take place. I will, however, show you where the absorption of these two dyes we have used takes place. This is a spectrum of the dye, it lets the ultra-violet rays through; in the green we have a great cutting off. Here we have the cyanine, which is a different colour altogether. It cuts off the yellow, and also the green; therefore, on the principle of work, we should expect that where absorption takes place in the dye, there the dye would be oxidised, and the silver reduced in consequence. I now

expose the three slips of paper above alluded to, and I will develop them before you. [The papers were developed in yellow light, as before.] The impression of the spectrum on

FIG. 7.



the eosine dyed paper flashes out, the part in the green comes out very strongly indeed. The blue dyed paper shows, besides the ordinary spectrum of the bromide, a band in the yellow. Finally, we have the undyed paper. The above diagram shows the effect obtained on cyanine blue.

### LECTURE III.—DELIVERED FEBRUARY 13TH, 1882.

I finished my last lecture by showing you the effect that dyes had upon sensitive salts. In my previous lectures I have not touched on the method of producing sensitive surfaces, except by the calotype or paper process, or by the wet collodion process; but I should be remiss if I did not mention the subject of collodion emulsions, which have been in vogue now for seven or eight years, but which have been supplanted, to a large extent, by gelatine emulsions. Whether that be an improvement upon the collodion process, except for certain things, I hesitate to say; but certainly, in a collodion emulsion process, we have a process which is admirably adapted, at all events, for landscape work. The collodion emulsion was originated, I believe, in September, 1864, by Messrs. Bolton and Sayce,

and a new era was opened out when they made their first emulsion.

Now, an emulsion is very simply formed, particularly a silver bromide or chloride emulsion; but, as far as I know, it has been rather a crux amongst photographers to make an emulsion with silver iodide. However, it is a very easy thing to do, and I propose roughly to show those who are initiated in emulsion-making how an emulsion can be made, and further, how iodide of silver can be made amenable to treatment. The point in emulsion making seems to be, to get the precipitate in as fine particles as possible, and it is said that this can only be obtained, except at very great cost of time and trouble, by first adding the soluble bromide, or iodide, to the collodion. If you take the trouble to add the

silver to the collodion, first of all, the aspect of emulsion making is entirely changed, and you can get any amount of fineness by adding the iodide or bromide to the silver contained in the collodion so long as you keep the silver nitrate in excess. In this bottle is some ether, and some gun cotton which is not dissolved up. In this test tube I have some nitrate of silver dissolved in alcohol containing a very little water. I simply pour this solution into the mixture of ether and gun cotton, shake it, and I find an *emulsion* of nitrate of silver *in collodion*, since the alcohol and ether dissolve up the cotton. In the old days, emulsion makers would have said there is something wrong in having an emulsion of silver nitrate, but I think I shall soon demonstrate to you that in reality it is all right. Now I will add an iodide to this silvered collodion. I pour a solution of potassium iodide into it, not drop by drop, but somewhat carelessly, and shake it up in the bottle at intervals, and as a result, we get a very fine emulsion. You would find if you reversed the operation, and put the iodide into the collodion first, and then added silver nitrate, you would have precipitated the iodide of silver at the bottom of the bottle, and in a form which would not emulsify at all. My advice to those who wish to make collodion emulsion (and gelatine emulsion) is to add the silver to the collodion (or gelatine), and then add the haloid salts afterwards, and you will get as perfect an emulsion as you choose. This formation, in so simple a manner, of an iodide emulsion, is a practical lesson which I hope will not be thrown away. I would just remark that if you examine this newly-made emulsion, you will find the iodide is in most minute particles, and that by transmitted light it is perfectly orange.

I have already shown you the colours of different haloid salts of silver under different conditions. I showed you two bromides, two iodides, and two chlorides, one of each of which had been boiled in gelatine, and the other unmodified, and you saw the different colours they transmitted. To-night I wish to show you a new form of emulsion, which is adapted to certain purposes, and which is sensitive to the red and the ultra red rays of the spectrum. If I had time I could show you that green is the most likely colour to absorb all below the red, and it was for this reason that I worked till I obtained a green-blue colour for the purpose I had in view. [The colour of the new form of bromide was shown

on the screen.] I propose to try and take a photograph with the dark rays of the spectrum which lie below the red. These rays, which were discovered by Sir W. Herschel, and whose properties were examined by Tyndall, by means of the thermopile, we can now analyse by means of photography. I will first, however, show you how very sensitive this form of bromine is to the ultra-red rays. There is what looks a very uninteresting picture on the screen, but still, it is sufficiently interesting for me to explain it to you. There are now, apparently, four black smudges, and these smudges were produced as follows:—A film of green bromide was prepared, and over it was put a card, punctured with holes of the same shape as the smudges, one-eighth of an inch away from it. Above the card, and about half an inch away, was placed a kettle of hot water, having a blackened surface. After considerable exposure, on development, I got the image of those holes in the card developed on the plate, and the result is the photograph on the screen. So you see that the dark rays of the kettle, or rather the energy of radiation from the kettle, was able to produce an image. This particular kind of bromide is very difficult to manipulate in a lecture, but I am going to be so bold as to make an experiment. I dare say some of you here who had the satisfaction of listening to Professor Graham Bell in his late visit, heard him discourse about the photophone; that is, as you know, an instrument which produces sounds in a telephone connected to a selenium cell acted on by light. In one form of this instrument, a beam of light impinging on the selenium, is intercepted by a revolving disc with alternate opaque and transparent sectors. He found, when he introduced between the source of light and the rotating disc a piece of ebonite, he still got the same effect, which was a matter of some interest. There were all kinds of explanations given about this remarkable fact. Some people supposed the ebonite took up the radiation, and gave it out on the other side, but I hope to show you that ebonite is transparent to the dark rays of the spectrum. I have some of this green bromide as a film on a plate. In front of that I have a piece of moderately thick ebonite. I propose to let the image of the carbon points forming the electric arc fall on the plate through the ebonite, by means of a lens. If the ebonite be permeable by the dark rays, we ought to get an image of the points on the bromide film when it is developed. As the rays have to penetrat

through a mass of ebonite, I propose to give an exposure of about thirty seconds, and I dare say we shall then find we get the points fairly delineated. It would be impossible to develop this plate in this light, so I will give it to Sergeant Jackson, and ask him to place it in the developer, and by-and-bye I will throw it on the screen. [This was subsequently done.]

For the sake of those who are uninitiated, I will show how very easy it is to develop an ordinary collodion emulsion plate. I am going to develop it with ferrous oxalate by means of a brush. Behind a negative is a plate coated with a collodio-bromide emulsion, and I will illuminate it by the magnesium wire. On taking it away from the negative, I place it in a little water, in order to make the developer flow, and then I develop the developer on the surface. It is rather a bold proceeding to manipulate a collodion film with a brush, but still I dare say it will answer. [The image was developed and shown.] The usual plan of developing these plates is to place them in a dish, and pour the developer over them. They can also be developed in the hand in the same way as a wet plate.

Now there is a great comfort in the collodio-bromide process, in that you are able to give local intensity to the image; and I hold that, for real artistic work, the great object is to be able to give local intensity to any part which the manipulator may judge expedient, so as to give it that tone and that vigour which an artist may think necessary. I have often asserted this before, and I am glad of the opportunity of repeating it. I do not believe any process is perfect until that power is placed in the hands of the manipulator; and the fact is that the next process which I shall describe is not perfect, as in it you are at the mercy of your plate, and you must let come out what will.

The process which I refer to is the gelatine process, which may be described as silver bromide, held in suspension in gelatine, in the same way that it is in collodion. The originator of the process, I believe I am correct in stating, was Dr. Maddox, who took the first picture on gelatine. I know there have been other claimants for the credit; but I believe, after consideration of the subject, that Dr. Maddox was the first person who used the gelatine emulsion with success. But of all people to whom we are indebted, there is no doubt, first of all, we are indebted to Mr. Kennett for the very perfect way in which he

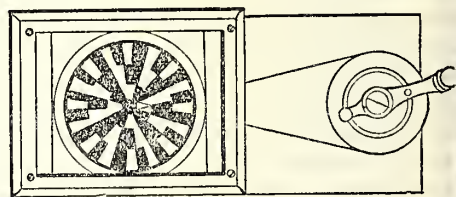
brought the emulsion before the public. Mr. Kennett laboured many years in improving gelatine emulsions. He, no doubt, bore the burden and heat of introducing this process commercially; but for the extreme rapidity with which gelatine plates can at present be prepared, Mr. Bennett must be credited with the full honour. Mr. Bennett showed how a gelatine emulsion could be rendered very sensitive by keeping it at a comparatively speaking low temperature in a liquid condition for many days. Seven days was not too long a time to get full rapidity of a gelatine emulsion. Colonel Wortley afterwards claimed that he could get the same sensitiveness with heating up to 150° Fahr. for a short time and then Mr. Mansfield capped it by showing that in a very few minutes you could get the same sensitiveness by boiling. Another method was then introduced of producing very sensitive gelatine emulsions, by Dr. Monkhoven, and that was by the introduction of ammonia with the bromide of silver. The ammonia process found many admirers, amongst whom was Dr. Eder, and no doubt the process which he has described lately, in which a large quantity of ammonia is added, gives very sensitive plates, and at the same time very vigorous pictures when the sensitiveness is not too great. But I think I may say that in England, a gentleman who is well-known amongst photographers, Mr. Cowan, has introduced an ammonia process, which certainly beats that of Dr. Eder. He emulsifies his bromide in a very small quantity of gelatine with ammonia, and then adds sufficient gelatine when the emulsion is ripened. Dr. Eder's method was to add the full amount of gelatine with the ammonia, by which means, of course, he got a certain amount of rapidity. By Mr. Cowan's method, you certainly get greater rapidity, and greater certainty. I thought it necessary to enter into this, because it has been imagined that your lecturer has been always an opponent of the ammonia process. I am not; but I honestly say I prefer what is called the boiling process in gelatine emulsion making; but if anything would convert me to the ammonia process, it would be Mr. Cowan's method.

Now what is the reason of this sensitiveness in the gelatine emulsion; for pictures can be taken in a tenth of the time necessary for a wet plate, and perhaps a thousandth that necessary for one of the old dry plates? First of all, we have seen on the screen, in the last lecture, that the bromide has a blue form. But you must not run away

with the idea that because anything is blue, therefore the molecules composing that emulsion are blue. It may be an agglomeration of red molecules, agglomerated together in such a way, that when light is scattered by it, it gives you the effect of blue light; and I believe I am right in stating that the most sensitive emulsion is that in which the agglomeration is in a red state, that is to say, the molecules themselves are red, and the agglomeration appears blue—the blue is there by accident, if I may say so. One reason why the gelatine emulsion appears so much more sensitive than the collodion emulsion is, that you can use a more powerful developer. If you separate bromide of silver which has been emulsified in gelatine, and which gives very rapid plates from the gelatine—and there is an easy way of getting bromide of silver out of gelatine—and place it in collodion, the extreme rapidity will be found to be gone, simply because you cannot use as strong a developer as you can with the gelatine emulsion; in fact, the property that gelatine possesses of acting as a physical restrainer comes into play; each little particle, or aggregation of particles, is surrounded by gelatine, which prevents the developer acting rapidly on them.

Again, the fact that by boiling, or by the ammonia process, you get a coarser deposit of bromide of silver, also points to increased sensitiveness, for the reason that I tried to give point to in my first lecture. For when sub-bromide of silver is acted on by the developer, you have metallic silver left, the last atom of bromine being taken away from the silver; and the moment you have freshly reduced silver in the presence of bromide of silver, and in contact with it, the bromide of silver can no longer exist, and, therefore, you have fresh sub-bromide formed, thus:— $\text{Ag}_2 + \text{Ag}_2 \text{Br}_2 = 2 \text{Ag}_2 \text{Br}$ , and this, in its turn, is reduced, and so on, until the whole of the particle is reduced. The faintest action of light on one of these particles will therefore show itself, which it would not do were this aggregation not so marked as it is seen when looked at under the microscope. Another reason of the increased sensitiveness is this (and I have no doubt it aids it very materially), that if you boil or heat bromide of silver, or any haloid salt of silver, with an organic substance, it has a tendency to separate into the metallic state. So by boiling, for instance, a gelatine emulsion of silver bromide, the silver has a tendency to separate into a metallic state; in fact, the bromide of silver then is in the state of very

tottering equilibrium; the bromine is ready to be given off at the very slightest disturbance of the molecule, much more so than before it is boiled. I think the fact that you so often get fogged emulsion when you over-boil, is proof of the statement that I am making. Now, if you were to ask me to illustrate the sensitiveness of a gelatine plate, I should take you down to the exhibition below, and show you first, not some of those marvellously instantaneous photographs which are there, but two less interesting-looking pictures, one by Mr. Henderson, which is a photograph by moonlight [afterwards exhibited on the screen at the concluding lecture], and another by Mr. William Brooks, which is a photograph of some underground cellars at Reigate, taken by lamp light. I think, if anything can show what gelatine plates can do, it is the fact that the candlelight and moonlight can be utilised for impressing the gelatine surface with an image. I have here another proof, perhaps, which will interest you as showing you how rapidly a gelatine plate can act. I propose to take an image of a rotating disc, having alternate transparent and opaque sectors, the illumination being the light of a single small spark. I have here an ordinary plate electric machine, and six small Leyden jars together with a discharging machine, the knobs of which are placed five millimetres apart. If the Leyden jars are charged to a certain point, the spark will leap across between these two knobs. The light from the



feeble spark will illuminate the rapidly rotating disc which I hold in my hand, behind which is placed a gelatine plate. [The apparatus was charged, and the spark passed between the knobs, illuminating the disc. The plate was then developed and shown.] The image you see, of the rotating disc is perfectly sharp [The disc was apparently motionless.] I daresay it will interest you to know with what speed that photograph was taken. The duration of the electric spark, for a distance such as I have here, has been measured, and found to be 42-millionths of a second. You have now some idea, of the immense velocity with which

the spark travels, and the extreme sensitiveness of the plate which I employ. This recalls to my mind a very early experiment, made in the daguerreotype days, where a piece of newspaper was placed on a rotating wheel, and by the light of a spark obtained from a battery of fifty large Leyden jars, a photograph was taken of the rotating newspaper. I believe the words were tolerably well defined. The time of passage of the spark was greatly longer than that which I showed you first, and it was immensely thicker and more luminous. I should suppose the spark from the large battery at the Royal Institution would take not less than a thousandth part of a second to travel, so that you see they were labouring under better circumstances than we are here. I have taken a photograph of this rotating disc in the camera, with only a spark from one jar, but it was rather a ticklish thing, so I preferred to carry out the experiment in the way I have done, rather than to risk a failure. But you may take my word for it, that if you had fifty Leyden jars, you could take a portrait of our Chairman with the greatest ease, by a flash from the spark, which would have a deviation of about a thousandth part of a second.

Dr. Vogel has recently introduced a new kind of emulsion, which is a sort of mongrel between collodion and gelatine emulsion. It is made with acetic acid, gelatine, pyroxylin, and bromide of silver; but I will not coat a plate to-night with it, as the smell of acetic acid is very strong. It is a very good emulsion, very clean, and very fairly rapid. I pass on from this, merely saying that plates are more readily coated than by gelatine emulsion, but less so than with collodion emulsion.

But we come now to a decided advance in photography, and that is the doing away with glass as a support for the emulsion. Anybody who has travelled, and had to make mountain ascents, will know perfectly well that glass is a serious drawback to the mountaineer; he would do anything to save himself the infliction of taking twelve whole plates up to the top of Mount Blanc. My friend, Mr. Warnerke, who is generally to the fore in all matters of photography, was to the fore in doing away with glass for carrying collodion films, and is now to the fore in doing away with glass for gelatinic films. He has perfected a process by which the photograph is taken on paper instead of on glass, and he has kindly brought here some illustrations to show the method pursued. First of all, he has a sensitive tissue, which can be made of any length. I do not know whether

he has made it a mile long, but certainly a great many yards, and it can be rolled on a roller, and exposed in the dark slide. By simply turning another roller, a fresh surface is brought into the plane of the focussing-screen. The sensitive tissue is developed in the ordinary way with alkaline development. Here we have it in the developed state. The film can be either stripped off, or else transferred to glass. In the latter case, we come to another point, which is a distinct advance in photography. Mr. Warnerke has found that when you develop a gelatine plate with alkaline development, that is to say, with pyrogallol acid and ammonia, the parts which have been acted upon by light, and which have been developed, become insoluble in hot water. He thus is able, after development, instead of using the hyposulphite bath to fix the print, to transfer it to glass, and wash away with hot water the parts of the film which have not been acted upon by light, and he gets a transparency such as I hold in my hand, and which no doubt you will examine with great interest by-and-bye. It should be noticed that, to do this, it is necessary that the back surface of the gelatine film should be exposed to the water, as in carbon printing, and this is secured by transfer to glass. Mr. Warnerke is not satisfied with doing away with glass for the camera, but he does away with glass for printing; and in order to accomplish this, he re-transfers the negative from the glass to a sheet of gelatine. I may say that the glass is freshly collodionised, which enables the film to strip off readily. In the picture before you we have an illustration of the gelatine film ready for printing, and here we have the print taken from the negative. An advantage of these film negatives is, that you can print from either side, each one yielding sharp prints, which is a desideratum when using the single transfer carbon process, and other such processes where reversed negatives are required. I think that Mr. Warnerke has really made a very great advance by enabling us to do away with glass. I only hope the time will come, before very long, when not only he himself, but his friends and the public at large, will be able to avail themselves of this excellent invention which he has now been cogitating for some time. I, myself, know he has been working at it for nearly two years. There is another part of his process which I shall have to speak about presently. But before leaving this part of the subject, I wish to call your attention to the "reason why" of the invention.

I do not like taking anything on trust, and I do not like seeing a thing and not knowing the reason of it. I hope that Mr. Warnerke will agree with me, when I say I think I have found the explanation of the insolubility of the film which has been acted upon by alkaline development after exposure to light. If you take a gelatine plate and expose it from the back very strongly to the sun-light, behind a negative, and then put it in tepid water, you will find there is a tendency for the part which has not been blackened by light gradually to dissolve away, and to leave the black image formed by light undissolved. What is the meaning of that? It means this, that bromine is liberated from the silver bromide, and the bromine renders the gelatine insoluble. If you take bromine and brush it across a plate, and put it in hot water, you will find where the bromine has acted, there the film will refuse to wash away. Again, if you take bromine water, and act in the same way upon gelatine emulsion with which plates will have been coated, you will find the gelatine emulsion becomes insoluble. I believe the rationale of Mr. Warnerke's process is that bromine is liberated in the gelatine, during the act of development. Now, you may say that the bromine is absorbed; so it is; but what becomes of it? If you add sulphite of soda, as in Mr. Berkeley's developer, I think Mr. Warnerke will bear me out in saying that there is no insolubility created by development. If you use a ferrous oxalate developer, there is no insolubility of the film created by such development. Why is that? Simply because the sulphite of soda is able to mop up the bromine, as is also the ferrous oxalate developer, as quickly as it is liberated, whereas the pyrogallic acid and ammonia is not able to do so. I have thrown this out as a hint for experimenters who wish to work further in this direction.

In the matter of gelatine films, we have Prof. Stebbing's, which are really workable. The gelatine emulsion is apparently flowed on an insoluble gelatine film on glass, which is then stripped. They are developed by placing them on glass. I have here examples of negatives taken on such films.

But I must now hurry on. The next point I am going to touch upon is the enlargement of negatives. Now, the question arises, how are you going to get an enlarged negative? Of course you will at once say "get a transparency by contact, and then enlarge it in the best way you can." "The best way you can is," of course, to do it very perfectly indeed; but, unfortu-

nately, by the wet process, an enlargement is very often sadly defective. The best way which I know of getting an enlargement of a negative, is one which was brought forward a few years ago by Mr. Valentine Blanchard, and it is this. He takes the original negative which he wishes to enlarge, and places it in an enlarging camera. He then takes a transparency of the exact size which he wants his negative to be. He next takes a piece of common albumenised paper, and prints that transparency upon it, and by this means gets a very soft and beautiful negative. If you have a hard negative, it is almost impossible to get a soft transparency by the wet plate process, but by this artifice of "printing out" your transparency, and using that as a negative, you get a decidedly soft paper negative. If you trace the reason of this, it is as follows:—When the albumenised paper is acted upon by light, we know it blackens immediately, and, of course, light acts less violently on the underneath portions where it has been blackened. Thus, in printing from a transparency, the most transparent portions first blacken, then the next most transparent part blackens, before the first blackened part becomes too intense, and so on. So you see, by the shielding of the film by the blackening action, you are able to get a softness which you otherwise would not get. I have here such a negative, which I prepared several years ago, by which you see we get some of this softness. Mr. Blanchard, I am sorry to say, has gone back from his old love, and recommends now, that you should use a gelatine plate instead of the albumenised paper. A gelatine plate is a very good thing, but I think the albumenised paper negative beats it, when you have to enlarge from a very small negative to a very large one. I think the grain of the paper, too, is an improvement in large photographs, and you get no grain in a gelatine negative. I will next show you how to obtain a paper negative by the ordinary lantern, but I must ask you to bear with me if I keep you rather long. I will make an enlarged negative from a transparency taken from one of my Egyptian negatives, developing it before you. This is ordinary paper, to which a couple of washes of bromide of potassium were given, and which, when dried, was floated on silver nitrate. Half a minute's exposure to the light coming through the transparency will be sufficient. I shall use the developer, which I recommended to you some time ago, the ferrous-citro-oxalate [The negative was developed and shown t



the audience.] So much, then, for paper enlargements. We now come to another great advantage of the gelatine process, which is that by it you can get soft transparencies. I am aware that it is said there is a certain amount of blurring in gelatine transparencies, but I am not prepared to say that is necessary, in fact, I should say it ought not to be the case, as I think I shall be able to show you in the next lecture. Therefore, if you have a hard negative by the common process, it is always possible, by the gelatine process, to get a soft negative from a gelatine transparency, in which case you can substitute for the paper, such as I used just now, a gelatine plate, or a collodion plate, or a wet plate, whichever you prefer. The main point to aim at in getting enlarged negatives is, to get thin, delicate transparencies, with every atom of detail present in them. If you get that, you can always get a decent enlarged negative from them. If the detail is blocked up, you will not do so, unless you use a paper printing process, such as I showed you, with the albumenised paper negative.

After these preliminary remarks, I propose to show you one of the new applications of the gelatine emulsion process, and that is the development of a print on paper coated with gelatino-bromide. The paper is prepared by coating ordinary paper with gelatino-bromide (of the most sensitive kind if you like). Such paper can then be exposed to the image formed by an ordinary magic lantern; by that means you can get an enlarged print. The lantern before you is a triple-wick oil lamp, and I think you will be able to see that I shall get a very good print indeed from the negative, which is at present placed in front of the condenser. [The negative in the lantern was a view taken by the lecturer of one of the caves of Ellora, in Western India. An exposure of half a minute was given, and then it was developed by the brush, with a ferrous oxalate developer.]

For my own part, I prefer gelatino-chloride paper, as it gives a very black image which beats the bromide out of the field altogether. The reason why the tone is black, is that chloride of silver, when developed, is developed in two states, in a red, or ruddy state, and also in a green state, and when you put red and green together, the result is not far from black. I think you will see, when this is developed, that we shall have the ruddy state first. I use the ferrous-citro-oxalate. It will not bear the ferrous oxalate at first,

although it may be brought out more quickly with it. Now, if I turned up the light, you would see it in the pinky state; as it goes on, the pinky state gives place to the green, and the two together make up the black, and you will see afterwards that this black is of a most beautiful hue. I want particularly to call attention to the beautiful black tone it has. On the table there are some plates prepared with gelatino-chloride, to show the same black tone.

[An enlargement on gelatine chloride paper was here made, and developed before the audience, the developer used being the ferrous-citro-oxalate.]

We may thus say that an advance has been made, when, by an ordinary magic-lantern, with a good negative, you can get a perfect enlarged paper print by development. Perhaps they will not have that lustre which albumenised prints have, but it is a matter of taste whether you like that gloss or not.

I have now to allude to Mr. Warnerke's invention again. He has found that he is able to mix with his gelatine emulsion colouring matter, and you will at once perceive the value of this. When you wash away from the gelatine the unaltered bromide of silver that is not acted upon by development, you get silver left behind, plus the colouring matter surrounding it. I have a developed print containing colouring matter, and to save time, I have placed it on a transfer paper. The image was developed with alkaline pyrogallic acid, and was placed in contact with gelatinised paper, rendered insoluble by chrome alum. I propose to wash away the soluble gelatine containing the bromide of silver and the pigment, to show what a power this discovery places in our hands. I first place it in hot water, and as soon as it has soaked a little, the outside paper on which it was developed will peel off, leaving the gelatine film on, what we may call, the transfer paper. The subject is one of Mr. England's statue subjects, of which he was kind enough to give me the negative. Stripping away the paper on which the print was developed, the picture remains on the transfer paper, and we have the image waiting to be freed from the soluble matter. The print before you was taken in my laboratory with the electric light; and had a very short exposure. The soluble matter is now gradually washing away, and the whites are gradually coming out, and we get a picture in the colour of alizarine. You can get almost any variety of colour; but it is not every colour the operator can

use, because some would destroy the sensitiveness of the gelatino-bromide, but most colours he can use. I can hardly thank Mr. Warnerke enough for the trouble he has taken in illustrating this part of my lecture for me. He has furnished me with pictures showing a variety

of tints, from sepia and photographic purple to almost any colour. This I may claim as a great advance in photographic printing, and I hope, before long, the public will have the advantage of this invention, which at present they have not.

## LECTURE IV.—DELIVERED FEBRUARY 20TH, 1882.

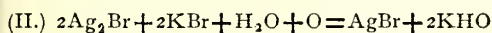
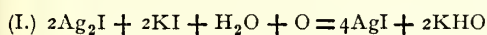
I have already shown you the example of a production of a positive from a negative, having previously to that demonstrated the production of a negative from a positive. I wish to commence this evening by showing you the production of a positive picture from a positive picture; not that there is anything essentially novel in it, but it points a moral to which I shall presently have to draw your attention. What I propose to do, is to take some sensitive iodide paper, expose it to light, and then soak it in a weak solution of potassium bromide, and next expose it to an enlarged image from a positive on glass. On developing, I think, the probabilities are that we shall get a positive picture. It is perfectly immaterial, as I am going to expose it to light, whether the paper sees the light now or not, and the small modicum of light we have here will make very little difference to this comparatively insensitive paper. [The paper was shown to the audience.] I now burn a small quantity of magnesium wire, in order to fully expose the sensitive surface. If I were to put a developer on that paper as it is now, it would at once blacken. Instead of applying the developer, I will place it in the solution of potassium bromide, then expose it under a transparency, and subsequently develop it. I will give it rather a prolonged exposure, for this paper is not very sensitive, and of course, the time in which this positive is produced depends on the sensitiveness. [A lantern image was thrown on the paper.] Half a minute with this light would be sufficient, but for safety's sake I will give 20 seconds longer. I will now develop the picture with ferrous oxalate, and a positive appears instead of a negative, which it would do under ordinary circumstances. In other words, the lights are reversed.

Before I draw any conclusion as to this, I will show what rays of the spectrum produced this positive picture, because this is an important item in the deduction I shall have to draw. I will take another similar piece of paper, and throw the spectrum upon it. You will recollect that we applied a solution of bromide of potassium to an exposed piece of paper, and that it was then exposed to the image. I will, therefore, expose this second piece of paper to the light from the magnesium wire, as before, and immerse it in a dish in which there is a solution of potassium bromide, and place it in the spectrum. I leave it to be acted upon for about half-a-minute. This I propose to develop on the screen, and by cutting off the light during development and again throwing it on, you will absolutely see the part of the spectrum which affects the paper. If everything goes right, there ought to be a bleaching action in the blue rays. The red rays will also exert a bleaching action if the exposure is continued for some time. I am not going into this action of the red rays, as it would carry me into too much theory; I simply want to show you the practical result of bromide of potassium on an exposed paper. On developing, you see we have the bleaching action caused by those portions of the spectrum which I mentioned.

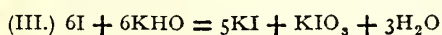


Now, if you will allow me, I will now point the moral. These may seem paltry experiments to bring before an audience, but those who are interested in gelatine plates, and believe there are a great many here who are

will now, perhaps, be able to draw an inference equally well with myself. All gelatine plates, without exception, I believe, are prepared with an excess of soluble bromide, and I will now ask you to consider what happens, supposing any bromide is left in the film. While the light is acting on the film, the bromide of silver is decomposed, and at the same time the bromide of potassium (or ammonium), is also being decomposed, and undoing the work that the light has done upon the bromide of silver; so that you see that the sensitiveness really got by gelatine plates with an excess of soluble bromide is only the difference between the effect of the light on the silver bromide, and on the bromide of potassium (or ammonium). I think those two experiments ought definitely to settle that gelatine plate-makers have not, as yet, obtained the highest sensitiveness possible, simply because they prepare their emulsions with an excess of soluble bromide. I may say, with reference to this, that Dr. Eder has recently shown that on immersing gelatine plates in a weak solution of silver nitrate, (in which is a little citric acid), though strong enough to neutralise any soluble bromide which may be left behind, an increase of sensitiveness, two or three-fold, is produced. The problem to be solved by gelatine plate-makers is this—How to get rid of any possible excess of soluble bromide in their gelatine films? When they do that, no doubt they will get more rapid plates even than they have done at present. I hope the effect on the minds of the audience of these two experiments will not be thrown away, as now you have seen that the same rays which act upon the silver bromide, act upon the potassium bromide. I will next show on the screen those interested in the chemistry of the subject the formula which represents the action which takes place—



In the first equation (I.) we have silver iodide, but a similar formula (II.) applies to bromide of potassium, and bromide of silver. In (I.) there is sub-iodide of silver, iodide of potassium, water and oxygen, and that forms iodide of silver, potash, and iodate of potassium. When you have more iodine or bromine liberated, we get—



or the iodine and potash combine, and form fresh potassium iodide, water, and iodate of potash.

When this reaction is finished, we have to go back to the equation (I.), and the same decomposition is repeated. The oxygen of course is a crux; where does it come from? It comes from the air. It will find its way through the gelatine. Gelatine is not impervious to the air. Dr Leeds has very recently found that this reaction does not take place when there is no oxygen present. So that you see, in order for this reaction to take place, there must be oxygen obtainable from some external source. If you prepare your emulsion with hydrochloric acid, as some do, you have nitric acid left in the film, and that will supply the necessary oxygen for this formula to take effect. I need not enter into details of what takes place with the nitric acid, it is sufficient to say that the nitric acid will supply the oxygen.

This leads me next to consider what causes the destruction of the photographic image. You may destroy the image on a photographic plate, or photographic paper, by any substance which will readily part with oxygen. You can destroy it, for instance, by bichromate of potash; you can destroy it by any of the ferric salts; or you can destroy it by oxygen-yielding substances, like permanganate of potash; ozone, per-oxide of hydrogen (hydroxyl); in fact, there is hardly any substance which will part with oxygen which will not destroy the developable image; the photographic image remains behind as a rule, though not always, but these reagents prevent it becoming developable. Here is paper prepared with bromide of silver, which has been already exposed behind a negative. After immersion in water, I propose to apply to it some of these destructive agents which I have already mentioned. First I will give it a streak of bichromate, next ferric oxalate, and next permanganate of potash. If everything goes right, on those parts to which these solutions have been applied, the image will be destroyed, or almost destroyed, and a little longer application of the solution would entirely destroy it. I now develop; parts of the image appears, but you see those parts which have been brushed over with the above solutions entirely refuse to appear. This demonstrates then that oxidising agents will destroy the developable image.

Now, I do not wish to detract from any developer, but this shows you the care you should take in seeing that your ferrous oxalate developer is tolerably fresh, for if you have a large proportion of ferric oxalate present with it, it will be very liable to "slow" your

plates, and those who are photographers will know what that means. If you take your pyrogallic acid which has been fully oxidised, you will find that it will play you the same trick as this ferric oxalate does, so that neither the ordinary alkaline developer nor the ferrous oxalate developer is certain to give you the best results unless it be fresh. Photographers take warning, and when using a ferrous oxalate developer, use it fresh! If you use the ferrous-citro-oxalate which I have introduced so often to your notice, you get the same result; it has the same bad qualities that the ferrous oxalate has.

I now come to the one other destructive agent of the photographic image, and that is bromine; and while I am on the subject, I should like to show you a neat way of exposing a transparency. It is not mine, and, therefore, I can praise it. Through Mr. Bolas's kindness I have here a phosphorescent plate made with calcium sulphide, which I propose to expose to light, then to use it as a source of illumination for obtaining a transparency. I now expose the phosphorescent plate to the light from magnesium wire, and then placing it over a negative, behind which is a sensitive plate, expose for 30 seconds. I next take a little bromine water, and brush it across the exposed sensitive plate; I rinse with water, and develop with ferrous oxalate. As I showed you in a former lecture, the ferrous oxalate is a very fair medium for cutting off the radiation which affects a bromide plate, and so I can develop it before you. The image begins to appear, and by degrees we have the image pretty perfect, except that, where the bromine has acted, there the image is totally destroyed, or very nearly so. This is a very simple experiment, but I did it for the purpose of leading you to another important point with regard to gelatine plates. Most of you are aware that when you have a pure bromide plate, it is very easily reversed as they call it, that is to say, instead of a negative there is a tendency for it to become a positive. The reason of that, I think, will be found in a measure in the experiment which I have just showed you. When you expose a bromide plate to the effects of light, anybody who has at all a keen sense of smell will perfectly well know there is some substance liberated which is somewhat pungent, and it will be found that it has a smell of bromine. If, therefore, you expose a plate for a considerable period—longer than it should be, that is to say—to light, what is the first effect? The first

effect is for the silver bromide to be decomposed at the surface, and bromine to be liberated in a gaseous state, part of it will ascend into the atmosphere, and part of it will have a tendency to go down into the film. As the light penetrates still further, the energy of the radiation will split up the bromide below into bromine and sub-bromide, and so on, and the part beneath the first part will be passed over by bromine liberated from the molecules immediately below; so that, by a continuation of this emission of bromine, you get, first, the top practically saturated, as it were, with the bromine from the lower particles, and, as we have just seen, when you have bromine applied to a plate that has been acted upon by light it destroys its developable powers—in other words, it forms fresh bromide of silver. In such is the case, you ought to have a reversal of the image at the top of the plate, and non-reversal probably at the bottom. I think I can show you this in the lantern. I expose two gelatine films, such as are prepared by Mr. Stebbing, behind a plate which is prepared with squares of different thicknesses of coloured gelatine; that is to say, it allows different gradations of light to pass through. On these graduated thicknesses of gelatine are painted opaque numbers. No. 1 shows the thinnest amount of tinted gelatine, and No. 25 shows the thickest amount of gelatine. With a moderate exposure to light of a gelatine plate behind such a screen, the whole of these opaque numbers ought to appear transparent on a more or less opaque background plate, when developed and fixed.

Now I will show you an experiment demonstrating what over-exposure will do. Two of Stebbing's films were placed face to face, and exposed for a considerable time to light behind a graduated screen. The results are before you. On the film nearest the graduated screen the whole of the numbers as far as 20 are reversed; that is, appear opaque on a transparent background. On the bottom film except No. 1, the whole of the gradations are perfect; that is to say, there is not a reverse image at all. Thus you see that a reversal takes place in the top part of the film, and not at the bottom. That is the point I wish to bring before you. No doubt this reversing action is partly due to the bromine which passes over the molecules which lie immediately below it. Not only that, however, but if you enter into the chemistry of the thing you will find that gelatine will take up the bromine, as it is liberated, though slowly

and that, when bromine combines with gelatine, one of two things happen—it either replaces and liberates hydrogen, or else a molecule which has the properties of hydroxyl. Either of these will combine with bromine to form hydrobromic acid, or yet another compound of bromine, which is equally ready to destroy the photographic image as bromine itself, or as any oxidising agent such as I showed you just now.

Now, before I quit the subject of oxidising agents, I should like to introduce to your notice a very remarkable utilisation of this oxidising process of photography which was proposed, and not only proposed, but carried out—there is a great distinction between the two, for we often hear propositions made by men who perhaps never have the pluck to carry them out—by Mr. Bolas. He, first of all, took an ordinary gelatine negative with proper gradations of light and shade. Then he wanted to reproduce it, so he took a gelatine plate, and immersed it in bichromate of potash, allowed the film to dry, and then exposed it to light behind the negative to be reproduced. You will see that in this exposure to light he had an oxidising agent present in his film, and that the oxidised parts were acted upon by light, leaving the other part intact, and by that means he got a reversed image. Now, he was aided by the fact that the gelatine is rendered insoluble to a large extent by bichromate of potash, but still that is not everything. On the screen is the original negative, and also the reproduced negative. These I had the pleasure of seeing manipulated at the Photographic Society. In regard to this process, we have a curious case of re-invention. We have lately had in the papers devoted to photography letters from France, in which a certain Captain Biny has been supposed to have invented this process. Across the Channel they have not the same facility for reading English, I am afraid, that we have for reading French. However, the discovery of Captain Biny's is nothing more or less than Mr. Bolas's discovery, and I hope Mr. Bolas will put in a claim for it.

Another use of oxidising agents is to enable us to get rid of fog. If you have a gelatine plate which has been exposed to light, and so has been fogged, you can get rid of that fog by immersing it in bichromate of potash. I have here a fogged emulsion plate of which the upper half has been immersed in bichromate of potash, the bottom half is completely veiled, but you will notice how beautifully clear the

top half is, where the plate has been immersed in the bichromate.

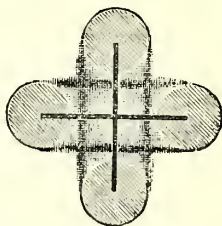
The next subject I wish to treat of is one which has been much misunderstood by many. The theory involved is not new to myself, but I think the results I shall show will be new as far as the audience is concerned. On this plate is pasted tin-foil, with various figures cut on it; first, there is a circle, then a line across, and so on. The image of these figures I now throw on a monster gelatine plate, the thickness of the glass being some  $\frac{1}{4}$  inch. Now, I ask you to observe what you see on it. You see every figure surrounded by a halo. Thus, you see, the circle is surrounded by a ring. You have a halo round every part of the images. If you come to analyse it, you will find that the halo surrounding the bright cross is made up of a series of rings similar to that ring which surrounds the clot of light. Now, I have here some wonderful elixir to get rid of these haloes.

FIG. 2.



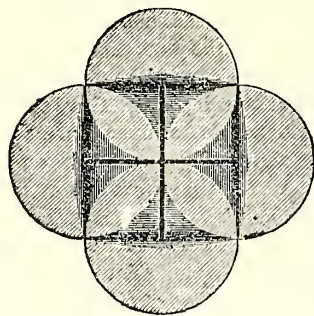
I touch the back of the plate where the cross falls with asphaltum, the halo vanishes. I move the plate a little, to get a fresh surface, and with red varnish I again touch the back of this plate, behind the cross, and now I have a white cross on a red background; to put the matter in words, according to the medium you place on the back of the plate, so is the reflection toned down. If I use a red varnish, this halation will have but little effect on the photographic plate, because it is red, and these red rays do not much effect the production of a change in the sensitive salt. The most perfect cure for halation is Brunswick black; there is no reflection from the back of the plate, and by that means you get rid of any tendency to fuzziness of the image, which was often a disgrace to photographers' pictures. I will now throw on the screen one or two of the absolute photographs showing different halations. One is from an ordinary plate, the other from a thick glass plate; when the thick one comes on the screen, instead of the cross remaining where it was, it was spread out considerably. [Shown.] When you come to analyse it mathematically, you will find the diameters of these rings depend on the thickness of the glass, together with the critical angle of reflection for the glass employed: that

FIG. 3.



the greatest intensity in the ring is fixed by the critical angle alone. That is a very important point, because there has been a good deal

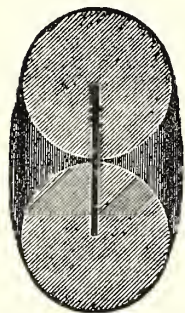
FIG. 4.



of controversy about it, which I will not enter into now. I think what you saw on the gelatine plate, and what you see on the screen now, ought to settle that point for ever. I will

show you some plates taken with an asphaltum backing; it is of no use giving improper backing; if you have anything which will reflect blue light, you get this blurring of the image. With a plate prepared with a backing of asphaltum, you can even expose it to a bright image of the sun without getting a halo round it. An astronomer in Germany has recently deluded the French Meteorological Office into believing that he has photographed the corona in full sunlight, but when you come to inquire into the matter, this corona is nothing else than the halation; not only that, but he has found the most extraordinary rays shooting out from it at certain times. When, however, you come to investigate the question, you will find that these wonderful rays, which are supposed to proceed from the sun, and thus to influence our earth, are nothing more than a certain reflection which the laws of optics tell us ought to be there.

FIG. 5.



Here is a simple method by which photographers can always be sure of seeing what amount of blurring they may get. If they take the trouble to place a gelatine plate, or any plate they wish to try, in contact with a slit cut in tinfoil, and then look through the back of the glass at a strong light, they will find it has more or less blurring round the slit.

Having so far digressed, I may say that the reason why you get apparently greater reversal in a photograph taken on a glass plate than you do in a paper negative, is because there is none of this halation to help it.

There is also another reason why reversal is

more difficult to secure on paper, in that the bromine has two ways to escape, one through the paper, and the other through the surface of the bromide. I hold in my hand an example of reversal on paper.

Now I will show you how you can get rid of this reversal altogether. The film before you was exposed 60 seconds behind a negative to the full sunlight, yet there is no reversal on it. How is that? Simple because I gave it something which, instead of allowing the bromine to attack the bromide of silver, that had been altered by light at once took it up. The substance employed was potassium nitrite. This shows that, if you want to get rid of the reversal of the image, you must give the plate something which will very rapidly absorb bromine, and should say something, if possible, which is non-organic, for the reason I have already stated to you in regard to its action on gelatin. Now, is it possible that you can give a film something of that kind, I say it is quite possible to do so, and those photographers who are experimenters no doubt might turn their attention to this point. In the meanwhile, I may say that the addition of iodide of bromine in a plate is sufficient to a very large extent, because, as I showed you in a former lecture, the sub-iodide of silver acts as a sensitiser to the bromide of silver; the consequence is, that those films which contain a large quantity, or even a small quantity of iodide, do not reverse in the same horrible manner as a pure bromide film will do. Perhaps a certain amount of anxiety may have been created in photographers' minds by a recent article in one of the photographic papers, in which a doubt was raised as to whether they can get iodide in their films. Let me once for all reassure them.

If you have iodide of potassium, and bromide of potassium to combine with silver nitrate, iodide of silver will always be present in your film for the iodide is formed always long before the bromide, and, therefore, the scare as to whether you have iodide in your plates or not, is one which need not be seriously entertained. As far as chloride goes, I leave that for another occasion to remark upon; but once again, all, if you have soluble iodide present when making an emulsion, you must have silver iodide in the film, and this will act as a sensitiser to prevent the reversal of the image.

I now come to a description of a most useful instrument introduced by Mr. W. nerke, which is known as a sensitometer; it consists of squares of coloured gelatine

different opacities through which light is allowed to fall on a sensitive plate. This sensitometer is meant to enable you to judge of the comparative rapidity of your plates. You have seen on the screen some of the images produced on glass, on paper, or on films, by the exposure of such a tablet as this, and it is a most useful instrument. To my mind, no photographer, be he amateur or professional, should be without one, or one similar to it. Mr. Warnerke has been the first to adapt this sensitometer to practical purposes. There are others in the field, of which we have a notable instance in that of Mr. Spurge; but for the time being I propose simply to call your attention to Warnerke's sensitometer. The method of operating is very much the way in which I operated just now. First, a phosphorescent tablet is exposed to magnesium light, and then allowed to rest a minute, placed in contact with the sensitometer plate, which is in front of

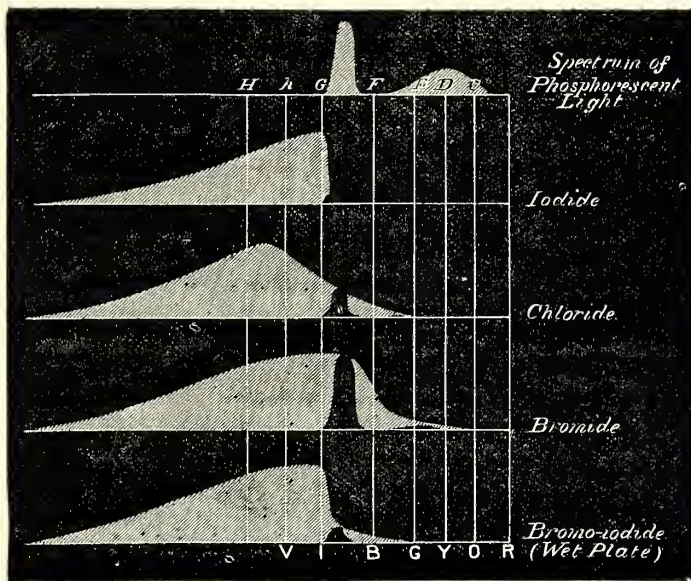
the plate to be tried. The exposure lasts for half a minute, and the plate is then developed. The last distinct number seen upon the plate by reflected light, before fixing, is read off. By a simple table you are able to see the comparative sensitiveness of two particular plates of the same kind. Here, owing to Mr. Warnerke's kindness, I have an enlarged apparatus, showing the way in which you read off the sensitometer. Suppose, for instance, you find the last number on one plate to be 20 in the one case, and 16 on another, if you take two such plates out in the field in the same light, and you want to know how much exposure to give in the one that registers 16, knowing that necessary for the one reading 20, how are you to do it? You take Mr.

Warnerke's instrument, such as we have here (but in miniature, of course), you place this opening at 20, you then cast your eye on the ring, look at 16, and find that the one that registers 20 is three times more rapid than the one that registers 16, and expose accordingly; so, in the same way, if you had one that registered 25, which is a very high degree of sensitiveness, and another 12, you would find that you would have to give the one 36 times more exposure than the other. I recommend this to the notice of practical photographers; I do not wish to act as an advertiser to Mr. Warnerke's sensitometer, but I merely advise them to get some sensitometer,

so as to prevent groping about in the dark as to what exposure to give to plates of different degrees of sensitiveness. There is nothing like picking a hole in your friends, if you possibly can, and now I am going to pick a hole in Mr. Warnerke's sensitometer; it is not a very grave one,

but still, one which ought to be noted; I want to show you what happens, supposing you measure all kinds of plates by such a sensitometer. First, let us examine what kind of light is emitted by this phosphorescent tablet. You will see, if I expose it to the light, it will phosphoresce, and the stronger the light the more it phosphoresces. Now, here we have a spectrum of the phosphorescent light, and when you come to examine it by the eye, it is found that there is one bright band in the indigo: there is a very faint light coming down as far as the red. When you photograph such light in the photo-spectroscope, nothing is indicated except the existence of the indigo band of light, and nothing in the violet or beyond; it is almost a monochromatic light which it emits, as

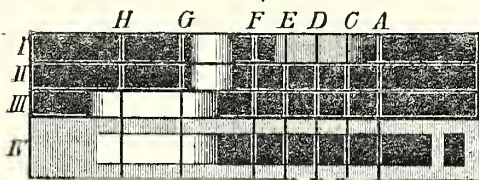
FIG. 6.



far as photography is concerned. Supposing we have to try some plate, the composition of which is unknown, with such a sensitometer, it will be seen that we may fall into serious error. On this diagram the mountain represents the intensity of light which is painted by the phosphorescent light on a plate. Supposing the plate only contained iodide, you will really see that the little mountain, which only affects the iodide, is only  $\frac{1}{30}$ th part of the whole mountain which would be there if you are using white light. If you only use chloride, it would be showing one-third only; whereas, if you use bromide, it would be unity, or as giving the maximum amount. If you try a wet plate by the sensitometer, you will find that it indicates only about one-fifth of the true value; that is to say, you would be wrong supposing you exposed a wet plate, and a gelatine plate according to the sensitometer; you would find that you had given five times too much exposure to the wet plate, simply because the bromo-iodide is most sensitive to those rays of light which are not present in the phosphorescent light. Hence, when using such a sensitometer with phosphorescent light, you must beware what you are about, and hesitate before you draw any exact conclusions.

This leads me on to the measurement of the intensity of light, for if we want to know anything about our plates, we must know what brightness of light we have. I again have to allude to Mr. Warnerke; he is a most facile inventor, and the photographic world is largely indebted to him for many ingenious contrivances. He has introduced an actinometer which is dependent on phosphorescence for its value. I have here a phosphorescent tablet which has been as little illuminated as possible. Now I will throw the spectrum upon it. [Shown.] This bright spec-

FIG. 7.

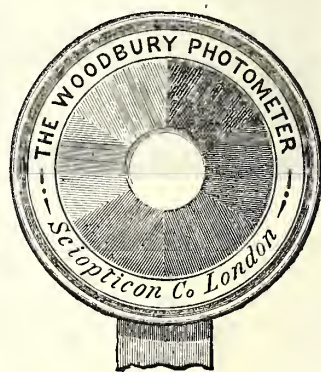


- I. Visual spectrum of phosphorescent light.
- II. Photographic spectrum of ditto.
- III. Rays exciting phosphorescence.
- IV. Rays which extinguish phosphorescence.

trum of phosphorescent light extends into the ultra-violet, but stops short at the place in the indigo, where the phosphorescent light is

emitted, that is to say, one spectrum end where the other begins. Mr. Warnerke has shown us that by exposing such a phosphorescent tablet to the action of light, by a ingenious contrivance, such as you will see downstairs, he is able to tell the photographic value of the particular light. This is a most valuable discovery, because phosphorescence is induced by very nearly the same rays as those which affect bromide of silver. If I allow the spectrum to play upon a fully excited phosphorescent tablet, we get another action. You will see that the phosphorescent light is diminished where the red and green have acted. These rays extinguish phosphorescence to a very large extent. With reference to this, there is a curious fact that below the red, as we know, there are rays which exist, and which, to a certain extent "de-sensitise" the phosphorescent film, and we have a darkening going on in that region. I have shown you this experiment, to demonstrate how you can desensitise this phosphorescent plate, viz.,—by allowing white light to pass through red or green glass, since this permits the passage of those particular rays which act as extinguishing rays. There is another very simple way, which I recommend to amateurs, of telling the amount of exposure to give to their plates, and that is by M.

FIG. 8.



Woodbury's photometer, which is the simplest thing in the world. Here we have a piece of bromide paper exposed to light for a minute, then read off again one of the tinted circles according as whichever tint

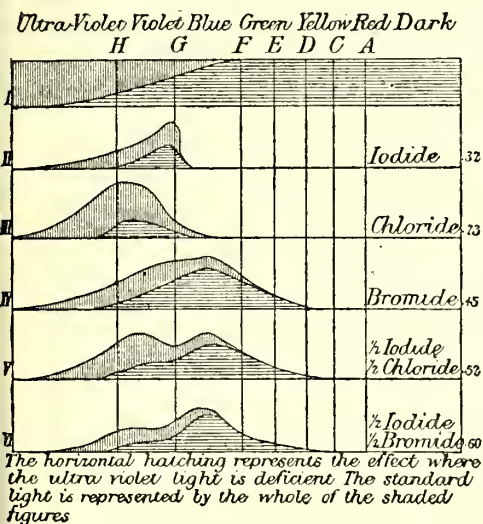
it agrees with; knowing the "light value" of the tint, you know what is the intensity of the light, and, therefore, what to give to the plate. A simple rule to remember is this, that if you use a bromide plate, only use a bromide paper for securing this tint; if you are using a chloride plate, use a chloride paper. Recent researches of mine have shown that the darkening intensity and the developing intensity go hand in hand; therefore, it will be found that when you have the number which gives the rig-



tint, you may always be sure of getting the right exposure. If a tint require two minutes to obtain, which corresponds with an exposure of a plate of two seconds, and you get that tint, and give two seconds, you will not be wrong. If it requires half a minute to obtain it, give the plate half a second's exposure, and you will be right. This is as useful an apparatus as you can have for the field. I do not know about the studio, but in the field some such device as this is almost a necessity.

I want to show you the theoretical as well as the practical necessity of using a photo-

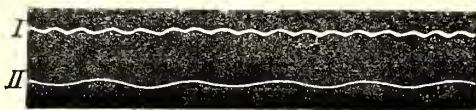
FIG. 9.



meter or actinometer of some description. Here we have these little mountains which signify the intensity of different parts of the spectrum. There are some bright days in summer, the light of which, when spread out in a spectrum, let us represent by a rectangle (I.), that is to say, they are all of equal intensity. I do not say they are, but you can represent them as such. There are other days in autumn or winter in which the ultra-violet will very much decrease. If you judge the exposure by the eye, you may be entirely wrong, and if you are using an iodide plate, you may only give one-third of the exposure you ought to give; for chloride only one-fourth; for bromide about one-half. If you are using one-half iodide and one-half bromide, you would give only two-thirds of what you ought to give, so that the eye is no exact judge of the exposure you ought to give; it depends on the amount of rays which exist in the ultra-violet, and that can only be told by a photometer of some description.

The next thing I propose to show you is with regard to drop shutters. I could talk to you for a whole evening on drop shutters, and even then I should not have finished, for there is a great deal in the philosophy of a drop shutter of which people have not dreamed. I am sure if I were to enter into minutiae, I should carry you beyond any endurable limits of time. I therefore, propose to show you one very easy plan of knowing what your drop shutter can do for you. We often hear said, "Oh, I exposed that plate with a drop shutter," and if the exclaimer is asked what length of exposure that was, he will probably confess that he does not know, or will say anything from 1-5th to 1-50th of a second. Now that is a very untidy way of photographing. It is decidedly misleading to say 1-5th of a second when it may be 1-20th. I will show you a way in which you can tell whether it is 1-20th or 1-5th of a second of exposure you may have given with a drop shutter. I have here a monster lens, with which, had I time, I was going to show you some tricks. It is not very valuable; I think it cost 6s. In front of this gigantic lens I have a gigantic drop shutter, and attached to the sides of that drop shutter there is a tuning-fork which cost 1s. I claim no monopoly. You take a common iron clamp, and attach it to the side of the shutter. Then you blacken a piece of albumenised paper by the side, and make the tuning fork vibrate. As the shutter drops, it traces its own vibrations, and tells you how many it has performed during the fall of the shutter. You know that an E tuning-fork vibrates so many times per second, and by simple measurement

FIG. 10.



you can tell at what speed your shutter is going at any part of its path. I dare say we shall be able to see that the tuning-fork leaves its mark on the smoked glass, which I have substituted for the albumenised paper above described. Here is another trace (II) made when gravity was aided by an elastic band. [The shutter fell, and the diagram was shown on the screen.]

I find my time is more than up; but before I close I should like to show you one or two

curiosities, as regards the scientific application of photography, and these are some composite photographs which were kindly lent to me by Mr. Galton, showing you what aid photography can give to anthropology. Here is a typical family composite portrait, composed of a mother and two daughters, all three faces being blended together. We thus get a likeness of the female branch of the family; then we have the father and mother, two sisters, and two brothers, giving the typical family group. Here we have another image, which is a typical group of engineer officers, and I am glad to see that they are so good looking. Here is one more, which is a typical group of sappers. I wish I had more time to go into the subject.

I cannot touch on printing processes at this late period of the evening, and therefore, I must ask your permission to close. I feel that what I have done has been very imperfect, but I have done it to the best of my ability, so far as time would permit. I may have done things I ought not to have done, but I have certainly left undone a great many things which I ought to have done, but I hope for all my shortcomings you will find some excuse. That this course of lectures has caused a certain amount of interest, is evinced by the continued large audiences I have seen before me, and I hope some abler lecturer, at some future time, will be able to complete what I feel I have only commenced to do, viz., give a *résumé* of recent advances in photography.



